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ECOLOGY OF THE ...
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**BY: SAMUEL C. SNEDAKER
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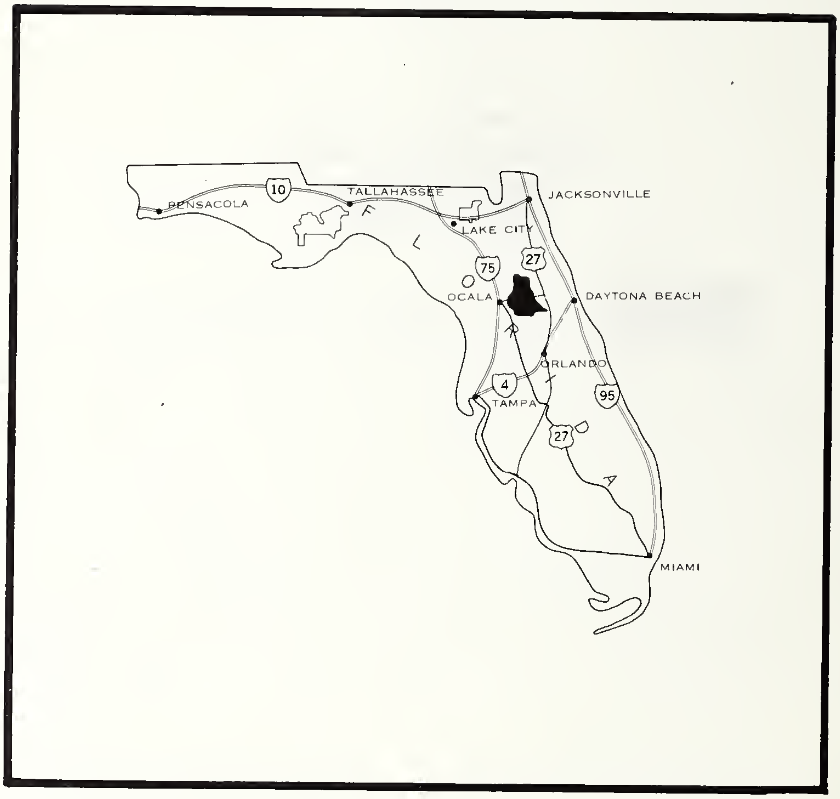

LOCATION MAP

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FOREWARD

As man develops his cities, crops, tree farms, industries, and networks of highways and powerlines across the landscape of Florida and the Nation, the ways and workings of nature's old ecological systems (ecosystems) are becoming scarce and unfamiliar to most Americans. On television and at attractions like Disney World, pleasant but untrue ideas about animals are romanticized (nature faking), and the main view many citizens have of vegetation is one of uniform monoculture, the kept lawn, green revolutions, or the "Dutch complex" of nature as neat, clean, managed, manicured, sprayed and replaceable with plastic carpets.

It is becoming more and more difficult for a child to experience the "balanced ecosystem" with its beautiful but dynamic fit of many complex interacting species. With a recent history of growth, our citizens have few handy examples left of steady no-growth regimes which are self-sustained by the management activities of animals, the special structures of plants and soils, and their work to provide a continuous cycling of nutrients. As man's new urban-oriented society becomes more complex, the individual citizen sees less and less of the whole basis for his own existence. As we understand the basis less, so common sense is less, and we may be able to make correct democratic decisions about our own place in the environment and its part in our survival. We see the trees but not the workings of the forest.

Thus, the remaining blocks of nature may be a place for our children to learn about ecology, which is the science of the ways and workings of complex nature. Man and his biosphere are part of that nature, and we need to build the properties of balance, recycling, complexity, stability, and survival into our new evolving landscapes of the biosphere. It may be in the very old ecosystems that the principles can be found, studie and taught simply in the schools.

In central Florida is an ancient ecosystem, the Ocala Scrub, that has become adapted to dry sand lands with a set of marvelously adapted and interacting species with behavior programs that are self sustaining. There is a continuous renewal of the properties of the land, a continuous replacement of life following life, and a capacity to adapt to adversity. Nature's pattern of diversity and division of labor is vivid there.

Perhaps all of the children of Florida and the tourists of the nations should stop by the Big Scrub to learn about the principles of ecology, about the recycling nutrients, about checks and balances, about the repair mechanisms for regenerating renewal following fire, about the ways rains recharge groundwaters to form spring runs, about speciation, and about the dispersion of the animals into territories and zones. Toward the needs of our people, Professors Snedaker and Lugo present in this book the Ocala Scrub as a whole system and with it they give and illustrate the principles of ecology that may be dramatized there. It may take some doing to teach these principles to younger children, for the abstractions of invisible pathways of nutrient chemicals, of food chains, and of controlling factors, are not so immediately enchanting as the individual antics of the rattl snake, the wild pig, or the pretty scrub jay; but the real message is its lessons about system designs for survival. Perhaps the symbol and pathway diagrams will help the reade see nature's designs in the Scrub. If we can teach the ecosystem's viewpoint using the fascinating life of the Ocala National Forest, perhaps our citizens can learn a systems point of view toward their larger landscapes and guide man within nature into a new era of stability that has compatible relationships of cities, farms, seas and wilderness inte acting as one stable system of space ship earth.

Howard T. Odum
Gainesville, Florida
June, 1972

PREFACE

In 1969, the principal author was approached by the Forest Supervisor's office (U.S. Forest Service, Tallahassee) concerning the need for a manuscript focusing on the ecology of the Ocala National Forest. Intended for Visitor Information Service personnel of the U.S. Forest Service, the manuscript was to provide a basis for interpreting the ecology of the Forest by blending recent advances in ecology with local examples. The task proved to be immense, for much of the necessary information was scattered in highly detailed scientific reports, the writings of naturalists and in the memories of local residents. This storehouse of specific information had to be sifted for relevancy and, through numerous field trips to the ecosystems of the Ocala, interpreted within an ecological context. The result was that, for the first time, a major portion of the north-central Florida landscape had been described as a series of inter-coupled ecosystems rather than as curious assemblages of species and novel interactions. However, to ensure that the book had appeal to those still un-acquainted with ecosystems, many natural history aspects were incorporated.

The preparation of the book was also a valuable learning experience for the authors in that time and time again, it was so apparent as to how little we really know about the structure and function of ecosystems. As a result, numerous field studies were initiated to fill the gaps in our knowledge. The lack of readily available information invariably stalled progress which resulted in obvious gaps and omissions. But hopefully this book will serve as a basis for other scientists to interpret, and continue studying the interesting and complex inter-relationships of the Forest and its components.

Systems ecology has been called the anti-discipline because it forces investigators to broaden their perspective beyond the limiting confines of the narrow scientific disciplines. To create a book, such as The Ecology of the Ocala National Forest, with the systems ecology perspective, required the assistance of many specialists in the sciences, the arts and the skills. To them, the authors are indebted. The core of this group, having been acknowledged as collaborators, is singled out for special thanks. The Chapter (VI) on Geology was prepared by Dr. Harold K. Brooks, Professor of Geology at the University of Florida. His manuscript, edited by the authors for this book, will be the basis of a future scientific paper contributing to our knowledge of the Ocala's geology. Seldom is one able to find a writer with the diverse capabilities of Mr. Allan H. Horton, a specialist in environmental communications. With Mr. Robert Miller's bibliographic assistance, Mr. Horton wrote the Chapter (III) on history. Mr. Douglas Pool is credited with mastering the mechanical details of assembling the final manuscript which included the difficult job of editing of the species listings and comments.

Four artist-illustrators contributed to the preparation of the diagrams and illustrations. Mr. Gary Hellermann spent a total of eight months on the energy flow diagrams and related illustrations, first with numerous sketchs and then in the preparation of the final plates. Mr. Pat Elliott, who grew up in the locale of the Ocala, created the habitat scenes in Chapter V. Ms. Peg Estey, a skillful scientific illustrator, combined her talent with imagination to illustrate the species interactions in Chapter VII. Ms. Estey also prepared the detailed illustrations of the animal species in Chapter VIII. Ms. Karen Snedaker, formerly with the Field Museum in Chicago, sketched the line drawings of animals also in that chapter. All of the original plates were done at a size up to five times larger than these appearing in this book. These plates were photo-reduced and printed by Image Designs of Gainesville, Florida.

The task of preparing and writing the text material required the assistance of many typists, most of whom worked nights and weekends always under the pressure of a progress deadline. Drafts were typed by Ms. Pat Marshall, Ms. Jerri Moore and final copy by Ms. Judy Simmons, and Ms. Marilyn Howell.

Special thanks are due the Florida Defenders of the Environment, Inc., for permission to use the faunal checklist which appears in the Appendix. This group, composed of scientists and naturalists, was responsible for the large effort necessary to assemble, in one list, the animal species reported for north-central Florida.

To the following, who each contributed time, effort and advice during the preparation of this book, the authors express their sincere appreciation.

Mr. Charles Bilgere
Ms. Leslie Brinson
Mr. Mark Brinson
Dr. Alberto Broce
Mr. Gary Evink
Dr. John Gamble
Mr. George Gardner
Mr. Buford Pruitt
Mr. Ernesto Striker
Mr. John Wester

Finally, the authors wish to bestow their kindest regards on Mr. William S. Craig who served as the contractor's representative in the U. S. Forest Service. Much of the content of this book resulted from Bill's suggestions based on his own personal experiences

CHAPTER I

INTRODUCTION

The boundaries of the Ocala National Forest (figure 1) circumscribes one of the most ecologically unique areas in the southeastern United States. Long known as the "Big Scrub" for the scruby nature of its vegetation, and its apparent marginal utility to man, the Ocala National Forest is now recognized as an asset of inestimable value to outdoor recreationists who arrive in increasing numbers each year and to society which benefits from its existence. The attraction and vlue of the forest are largely due to its physical and biological diversity which make it an ecological wonderland; a microcosm of the inland Florida landscape.

To the arriving forest visitor, the Ocala National Forest is indeed a Big Scrub, of apparent value only to the pulp-wood industry, the seasonal huntsman and the warm-weather enjoyers of the oasis-like springs, lakes and waterways. The easy-to-please leave content with but maybe slightly altered impressions. The amateur naturalists, the explorer, the curious, however, discover an environment rich in natural and human history, a land of sand pine forest, sub-tropical hammocks and the Yearling, tales of cannibals, of wolves, panther, disappearing creeks and small turtles which dig decoy egg-nests to fool marauders. To these, the Ocala National Forest is a life-enriching experience about which often too little can be learned during a brief visit.

This book, The Ecology of the Ocala National Forest, has been prepared to enable the forest visitor of any persuasion to learn whatever is needed to satisfy some of his inquisitiveness and receive the maximum obtainable benefits. Each chapter is a complete unit surveying the subject in question and may be used without referring to other chapters. For those so inclined, a perusal of the entire book reveals a thoroughly cross-referenced, cohesive treatment of the ecology of the area, including the pertinent human aspects. In several of the chapters, the format has been designed to permit use as a field guide to the more interesting plants and animals. Throughout the book, topics of major interest are illustrated, many in such a manner as to provide a graphic summary of text material.

The theme of the book is, of course, ecology and is carried through from chapter to chapter based on the conceptual background developed in Chapter II. A glance at this material will evoke from the majority of readers an apprehension about one's understanding of what ecology really is. Closer examination only serves to reinforce an uneasy sense of bewilderment. One should understand, however, that ecology as a scientific discipline has rapidly moved from the descriptive-study approach of the natural historian to the quantitative emphases of the systems ecologists. Employed as the vehicle of understanding this book, the systems approach will be new to the layman as well as many scientists. Although systems ecology is not the sole quantitative aspect of ecology, it alone, unites both structure and function. With this perspective, the structure and function of ecosystems can be interpreted to show that all components of the landscape bear relationships with one another; that no portion of the biosphere (earth and the life upon it) exists in an ecological vacuum. The reader, wearing the literary glasses of a systems ecologist, sees the Ocala National Forest Regional Ecosystem as a system composed of a seemingly infinite array of finely programmed subsystems; the smaller systems all contributing to the wholeness of the larger ecosystems. The glasses are in Chapter II.

The vast tract of land, woods, and water, known as the Big Scrub, has been managed as a National Forest for only a fraction of its existence. It appearance today reflects millenniums of evolution and, only recently, sundry alterations by man. Prior to the assumption of responsibility by the U. S. Forest Service, the Big Scrub has been hunting ground, homestead, and lively-hood to untold thousands of people. The earliest uses could be characterized "in balance with nature", for its resources were apparently never used to the point of exploitation. The arrival of the Europeans, the Industrial Revolution,

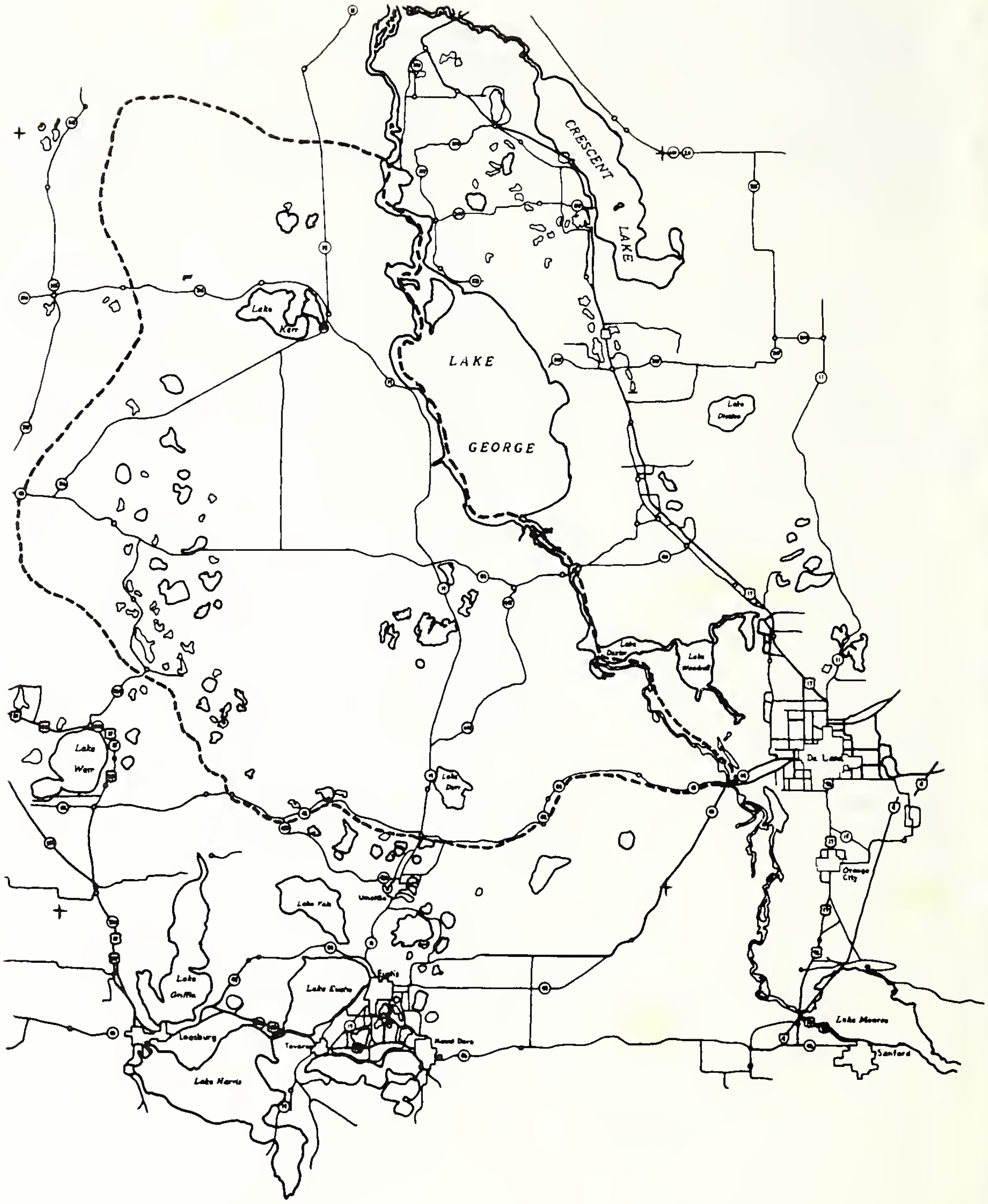


Figure 1.-The boundaries of the Ocala National Forest.

and the tools and wherewithall to massively alter vast portions of the landscape have tipped this balance however slight. Fortunately for the Big Scrub, its apparent marginal utility to man has served to maintain its integrity against the onslaughts of civilization. Chapter III is a compressed recap of the history of man's relationships with the Big Scrub including the role of the U. S. Forest Service.

Ecosystems are the largest units of biological organization and are molded in part by the physical environment. Within the Ocala National Forest Regional Ecosystem the physical environment may be viewed as an environmental continuum ranging between bottom lands with abundant moisture, and dry sandy hills. The moisture gradient is extended to the dry extreme by areas of loose permeable sands which permit rapid downward loss of water. The availability of water in the environment affects the heat balance in that evaporation and transpiration have cooling effects which help to maintain lower temperatures. The environmental continuum, or gradient, of heat and moisture exists despite the fact that the annual receipt of precipitation and insolation is probably not too different among contiguous ecosystems. The interaction of physical factors associated with geology, soils, climate and hydrology, described in the overview in Chapters IV and V, permits the reader to develop a greater understanding of the importance of the physical environment on the diversity of ecosystems within the Ocala National Forest. With this background, the gross ecosystem adaptations, e.g., species dominance and physiognomy (overall appearance), apparent to even the casual observer, are easily understood.

Ecosystems, very generally stated, are assemblages of species living together as a unit and interacting with themselves and the physical environment. The study of life histories of individual species, however, usually reveals very little about the life history of the system of which species are but components. Likewise the study of the life history, or structure and function, of an ecosystem can be achieved without delving in the fine detail of component species. Both aspects of ecology are required to attain an understanding of life within the Ocala National Forest. Chapter VI provides a traditional view of communities which is presented first in order to develop a framework for viewing a community as a complex organism called an ecosystem.

The chapter (VII) on symbiotic considerations explores the ways in which the living components of any ecosystem interact with one another. The example interactions are highly simplified to illustrate the point. In nature, however, it must be recognized that each species is capable of expressing all forms of interaction with other species depending on the particular circumstances. This chapter may also be considered a primer in systems ecology because it describes the basic interactions and interrelationships in the language of the systems ecologists. Relationships are described both verbally and in an simple systems diagram. The reader, by becoming familiar with relationships and in the ways they may be expressed, acquires a foundation for understanding the complex relationships of entire multi-species ecosystems.

Assemblages of species, all interacting with one another in space and time, represent only one aspect of a dynamic ecosystem. To view the entire system in terms of its structure and function, one must also understand how the biotic and abiotic (living and non-living) components are interrelated. To achieve this, all of the independently treated material presented in the first chapters are drawn together to describe some of the ecosystems of the Ocala National Forest. In a sense, Chapter VIII summarizes both the book and the Forest. The presentation format, discussions, diagrams, and illustrations, used throughout the book is highlighted in this chapter. In addition to the educational value contributed by the whole-systems approach, the complex diagrams in Chapter VIII also have a utilitarin value. Thus, the ways in which the model diagrams may be used by ecosystem managers to balance man and nature are explored.

Complete descriptions of the animal species, characteristic of north-central Florida and the Ocala National Forest, would have attempted to duplicate the many field guides available to the Forest visitor. Thus, a checklist has been included as an Appendix for the naturalist observer. Comments on certain species and several major families appear in the chapter (VI) on communities.

CHAPTER II

ECOLOGICAL BACKGROUND

INTRODUCTION

Today, ecologists are shifting their academic orientation away from the traditional approach of the natural historian toward a more quantitative and objective analysis of life systems. Although much remains to be learned from descriptions of habitats and habitat occupants, the modern-day ecologists is more concerned with integrative studies of the complex ecological systems of the biosphere. The components of these ecological systems are not isolated entities, but rather exhibit intimate relationships and express an interdependency of existence. Similarly, the world's ecosystems are interlinked to form the living biosphere.

Technology has often been the cause of ecological "catastrophies" but at the same time it has made available techniques for the study of the complex structure and function of ecosystems. One of the modern approaches to the study of ecosystems is based on the energy language developed by Dr. Howard T. Odum from the University of Florida. Through a knowledge of the laws of energy and the use of Dr. Odum's energy symbols, it is possible to construct diagrams which represent ecological systems. These diagrams are based on energy as the common denominator of ecosystem function and provide graphic representations of the interactions of biological systems with their environment. An added asset of the energy language is its mathematical foundation which facilitates the transfer of energy models to computers (analog, digital and hybrids) for simulation and analyses. The energy language is used here to illustrate many of the ecological principles and relationships and to describe examples in the Ocala National Forest. Unfortunately, a full discussion of the energy language is beyond the scope of this book and the reader is referred to the Bibliography which cites the original papers describing the derivation and use of the symbols. For the reader's convenience, figure 2 summarizes the symbols and their meanings.

The Concept of Spaceship Earth

With the advent of space travel and the current emphasis on pollution, our vocabulary is being enriched with such words as suborbital, boosters, eutrophication and photochemical oxidants. A new term, a product of this age combining both technological and ecological insight, is the one comparing the earth to a spaceship - "Spaceship Earth". Our understanding of the concept of the ecosystem depends, in part, on understanding this term.

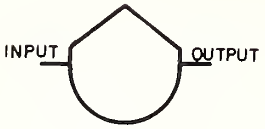
The structure and function of a spaceship is designed to perform a dual role; it is a complex vehicle constructed for traversing great distances in space and it serves also as a life support system for the occupants. The giant rockets propel it on journies through space and the Mercury, Gemini or Appolo-type capsules sustain and nourish the astronauts. As shown in figure 3, a fully provisional spacecraft is a self-contained system, because once severed from the earth-bound gantry it operates without any further inputs. Fuel is burned for propulsion and the stored food is consumed by the astronauts who produce metabolic waste products. The use of these internal energy storages reduces the ability of the craft to travel extended distances or to support life in perpetuity. For these reasons, space flights are preplanned with great accuracy and precision.

The planet earth also travels through space, but its role as a transportation device is negligible. The primary difference, however, between a spacecraft and the spaceship earth lies in the capacity to store energy and support life. The ability to transform solar energy into chemical energy (food) gives the earth a dominant role as a life support systems capable of maintaining life as long as solar energy is available.

The description of the spaceship and the analogy with earth are of fundamental ecological interest to our introductory discussion. Both are examples of ecosystems and

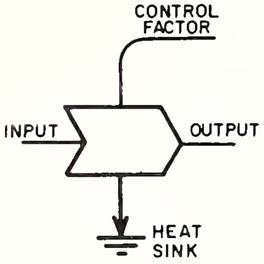
Figure 2a-n.-The energy language symbols.

a. Passive storage



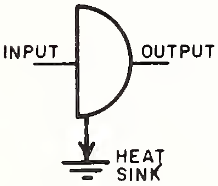
The passive storage symbol shows the location in a system for passive storage such as moving potatoes into a grocery store or fuel into a tank. No new potential energy is generated and some work must be done in the process of moving the potential energy in and out of the storage by some other unit. It is used to represent the storage of materials or biomass in systems.

b. Workgate



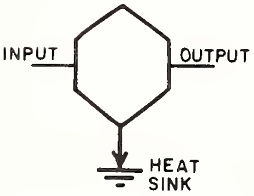
The workgate module indicates a flow of energy (control factor) which makes possible another flow of energy (input-output). This action may be as simple as a person turning a valve, or it may be the interaction of a limiting factor in photosynthesis. It is used to show the multiplier interaction of two system components.

c. Self-maintaining consumer population



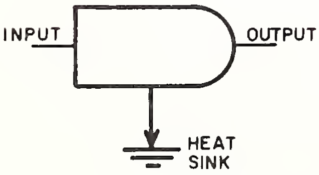
The self-maintaining consumer population symbol represents a combination of "active storage" and a "multiplier by which potential energy stored in one or more sites in a subsystem is fed back to do work on the successful processing and work of that unit. It is used to represent populations of animals in ecosystems.

d. Pure energy receptor



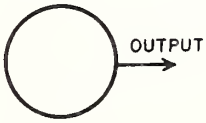
The pure energy receptor symbol represents the receptio of pure wave energy such as sound, light, and water waves. In this module energy interacts with some cycling material producing an energy-activated state, which then returns to its deactivated state passing energy on to the next step in a chain of processes. This symbol is used to represent photosynthesis or chlorophyll light-reception in leaves and other photosynthetic tissues.

e. Plant population

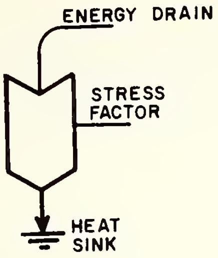


The plant population symbol is a combination of a "consumer unit" and a "pure energy receptor." Energy captured by a cycling receptor unit is passed to a self-maintaining unit that also keeps the cycling receptor machinery working, and returns necessary materials to it. The green plant is an example.

f. Energy source

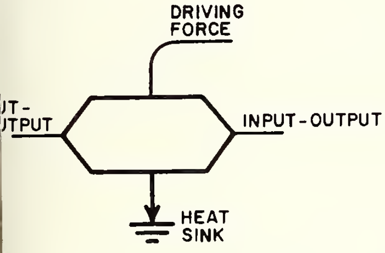


The energy source symbol represents a source of energy such as the sun, fossil fuel, or the water from a reservoir. A full description of this source would require supplementar description indicating if the source were constant force, constant flux, or programmed in a particular sequence.



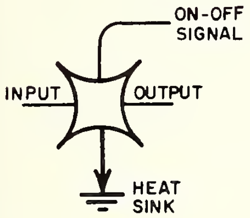
g. Stress

The stress symbol defines the drain of calories of potential energy flow. When a system is stressed, some of the potential energy that was available to do the work is lost. The stress symbol is an inverted workgate with energy from the system being drained into a heat sink by an environmental factor (the stress) shown on the opposite side of the workgate. This symbol may be used, for instance, to show the effect of a pollutant on a stream.



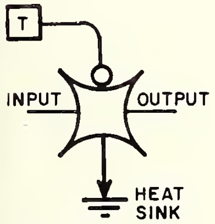
h. Two-way workgate

The two-way workgate or forced diffusion module represents the movement of materials in two directions as in the vertical movement of minerals and plankton in the sea. The movement is in proportion to a concentration gradient or a causal force shown operating the gate. The heat sink shows the action to follow the second law of thermodynamics.



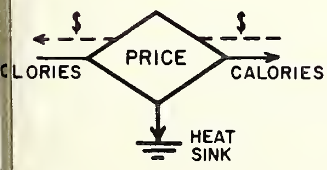
i. Switch

The switch is used for flows, which have only on and off states controlling other flows by switching actions. There are many possible switching actions as classified in discussions of digital logic. Some are simple on and off; others are on when two or more energy flows are simultaneously on; some are on when connecting energy flows are off, and so forth. Many actions of complex organisms and man are ON and OFF switching actions such as voting, reproduction, and starting the car.



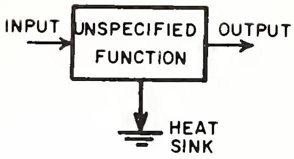
j. Logic switch

The logic switch follows the same kinetics of the ON-OFF switch described above. In order for the logic switch to be operative, however, a certain value in the module controlling the ON-OFF signal must have been attained. When the threshold "T" is high, flow is off. For example, when simulating the effects of water level on a biological process, a threshold value, representative of a critical level, is used to turn the process ON or OFF. This symbol is useful in working with analog computers with logic boards.



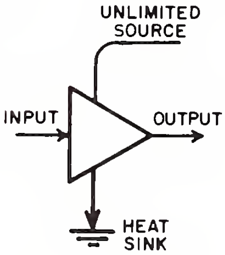
k. Economic transactor

The economic transactor symbol is used for systems that have money cycles as well as energy flows. Money flows in the opposite direction to the flow of energy and the concept of price which operates among human bargains adjusts one flow to be in proportion to the other. Thus a man purchasing groceries at a store receives groceries in one direction while paying money in the opposite direction The heat losses of these transactions are small since the work involved is small. If there are complex structures regulating the transactions the costs of the coupling may be great.



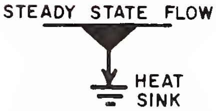
l. Box

The box symbol is used when an unspecified action is being represented, or when the function is unknown or unimportant to the point being made. If the function is known, but no specific symbol is available, a box may be used with the function written inside.



m. Constant gain amplifier

In this module the amount of energy supplied from the upper flow is that necessary to increase the force expressed in the system by a constant factor, which is called the gain. For example, a species reproducing with 10 offspring has a gain of 10 so long as the energy supplies are more than adequate to maintain this rate of increase. This symbol is used to represent exponential functions such as rapid population growth.



n. Heat loss in steady-state flow

This symbol is used to represent the energy losses associated with friction and backforces along pathways of energy flow. For simplicity, we consider the heat loss along a pathway to be understood and therefore omit it. Remember that all work results in a loss of heat.

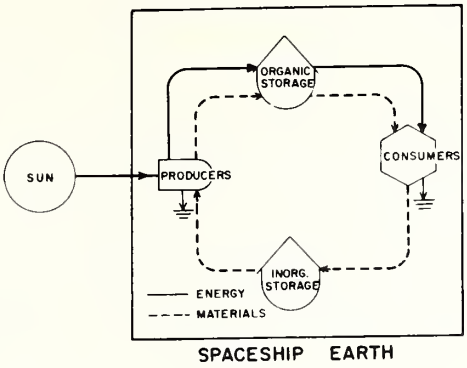


Figure 3a.-The basic components of the spaceship earth. The radiant energy of the sun is converted to chemical energy through photosynthesis by the earth's producers (plants). This energy, in the form of organic material, is stored for subsequent use by the earth's numerous consumers. During photosynthesis, inorganic materials, used as plant nutrients, are incorporated in the stored organic material which are passed along to the consumers. Unlike energy which once used is lost as heat, the inorganic materials are eventually released by the consumers for re-use by plants. Note that energy is always being received by spaceship earth and always being used and lost as heat. The inorganic materials remain in constant circulation.

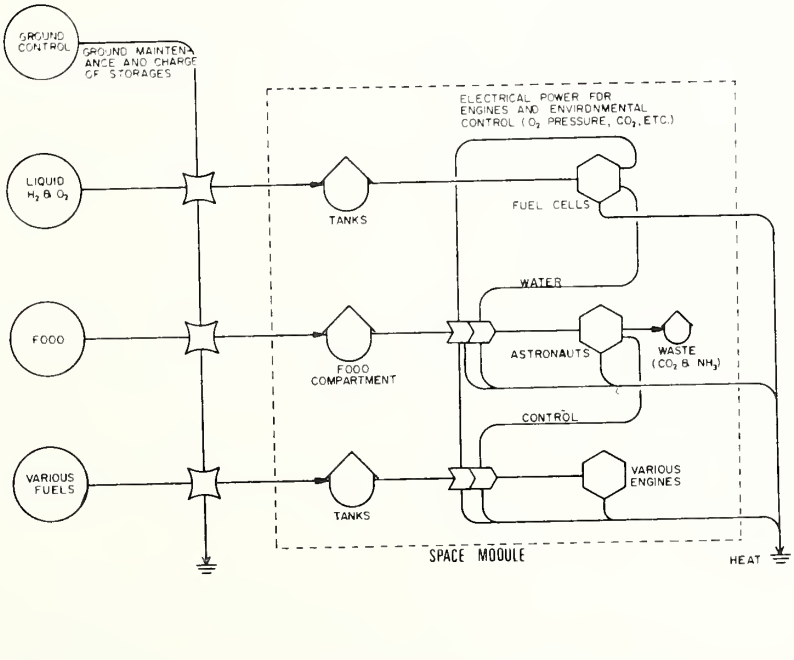


Figure 3b.-Some of the basic components of a space module in constrast to earth. Both energy and materials are brought in from outside; loaded through the activities of ground control. While connected to the earth-bound gantry, the module with its own internal components remains dependent on earth resources. Note that all of the energy is in the form of energy-rich chemical compounds. Prior to blast off, the storage tanks are filled to capacity.

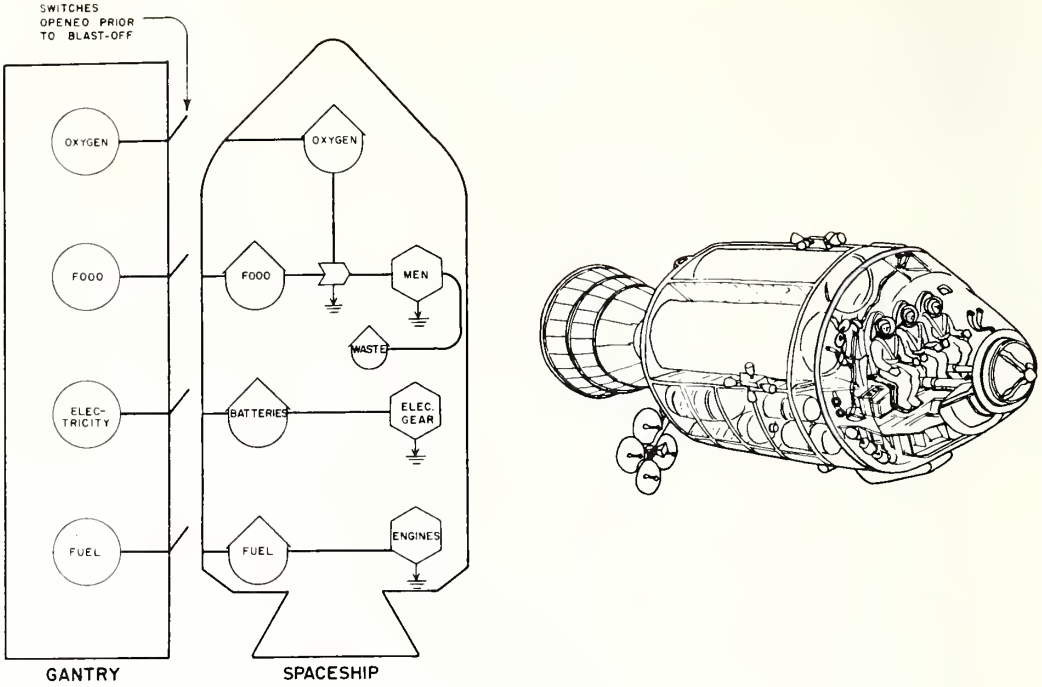


Figure 3c.-The isolated space module. At blast off, the gantry is disconnected from the module which then becomes a temporarily self-sustaining unit. The fuel powers the engines for the space flight and the batteries run the internal motors and equipment. The three astronauts are maintained through utilization of the food and oxygen stored on board. All wastes, except heat, remain within the module during the flight. The spaceship, unlike earth which constantly receives new energies from the sun, is a functional unit only until the storage tanks are emptied.

ecosystems are life support systems. We may apply the name ecosystem to the earth with the same confidence that we apply it to the spaceship. They both support life and both possess the elements that characterize life, namely an area or volume, an energy source, living and non-living components, pathways for energy and material flow among components, and an envir ment that modifies the behavior of the components. It is most important to note, however, that the life support services provided by the earth are free to man. We take them for granted failing to realize how much it would cost to provide them through technology. Consider how much it cost to provide the life support services to three men in a space craft.

It is apparent from this preliminary definition of ecosystems that they are dynamic units with the conceptual emphasis on function rather than structure. It is also apparent that the boundaries or area of the ecosystem are of little importance provided that one describes accurately both the internal processes within the system and the external exchanges with its surroundings. For example, in describing the overall functions of a boat as an ecological system, one would have to account for the loading, storage, internal movement and off-loading passengers, cargo, fuel, food and wastes. When studying natural system the interest is on the input, storage, internal movement, and output of solar energy, plant and animal species (genetic material), organic matter, fluids and minerals. The concept of the ecosystem is equally applicable to both natural and social systems provided one specifies the energy source, the boundaries, and the flows and storages of all pertinent material

THE STRUCTURE AND FUNCTION OF ECOSYSTEMS

The Sun: the Source of Energy

The energy to perform work in the biosphere is ultimately derived from the solar radiation of the sun. This solar energy is emitted in all directions from around the sun and a very small proportionate amount impinges upon the earth's atmosphere. A portion of this solar radiation is reflected off the earth's atmosphere back into space and another portion is absorbed by the atmosphere where it contributes to the powering of global environmental processes revealed in part by our weather cycles. The remainder of the solar energy flow that is neither reflected or absorbed by the atmosphere filters through and impinges on the earth's surface. Here it is used to power all biological processes and to maintain local environmental conditions. The latter is discussed more thoroughly in Chapter V under climate.

In accordance with the Second Law of Thermodynamics, the flow of energy from the sun is received in a concentrated state and is ultimately dispersed as heat and lost from the biosphere through re-radiation back to space. In broad global terms, the gains or inputs of solar energy into the biosphere over time equal the heat losses (figures 4 and 5).

Of particular interest to ecologists, is the fate of the solar energy incident on the earth's surface and how it is used prior to its loss as heat. Before discussing the use of solar energy on the earth's surface, it is necessary to describe the heat budget for a very small portion of land area. Shown in figure 6 are the forms in which solar energy is received on the earth's surface and the ways in which this surface, were it covered with small plants, ultimately loses this energy as heat. The fluxes (pathways) shown in the diagram are defined as:

Gains
  (1) direct sunlight - filters through atmosphere
  (2) reflected sunlight - reflected from atmosphere
  (3) atmospheric heat radiation - absorbed in atmosphere and re-radiated earthward
  (4) scattered sunlight - radiation scattered by atmospheric constituents
Losses
  (1) reflected - sunlight reflected directly off terrestrial surfaces
  (2) re-radiated - absorbed by terrestrial surfaces and re-radiated skyward
  (3) conduction - direct transfer by contact heating of particles
  (4) convection - direct transfer by mass movement of heated particles
  (5) transpiration - heat loss accompanying water loss from plants.
  (6) evaporation - heat loss accompanying vaporization of water

Note that the energy transformation process is not necessarily instantaneous. Some processes involve periods of accumulation followed by periods of loss as illustrated occuring in soil. The sequence of heating, then cooling (i.e., losing heat) in the physical environment occurs on daily and seasonal cycles and also on much longer cycles coincident with geological time scales.

Biological entities also accumulate energy through the process of photosynthesis. This energy is not accumulated as heat, but as potential chemical energy (concentrated) which may later be used to do work in an ecosystem, and once used, lost as heat. Only a relatively small portion of the solar energy spectrum is used by, or affects, plants. The portion of the electromagnetic spectrum of interest in this regard is the visible light range and portions of the ultra-violet and infra-red radiation. In our discussion of the ecology of the Ocala National Forest we will be primarily concerned with the infra-red heat radiation and the portion of the visible spectrum that is absorbed by plant pigments such as chlorophyll.

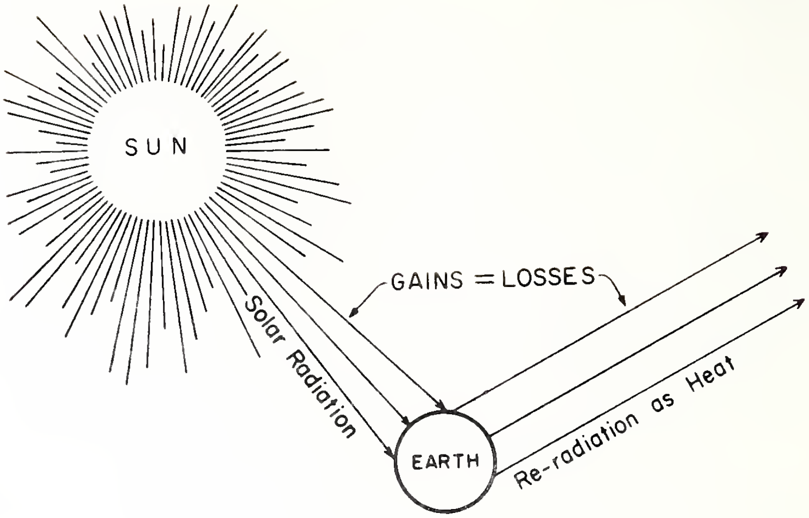


Figure 4.-The global heat budget. Over time, the quantity of solar energy received by the earth equals the loss of heat energy re-radiated back to space. As a result, the earth as a unit maintains a relatively stable temperature. This is the basis of the global heat budget.

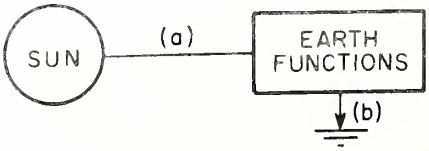


Figure 5.-The global heat budget expressed in the energy language. The input, flow (a) equals over time, the heat loss, flow (b), back to space. During the transition in the biosphere, solar energy powers the work necessary to maintain our life support system.

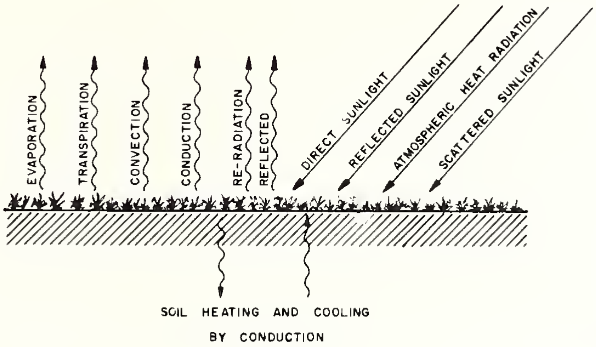


Figure 6.-The energy inputs and losses on a plant-covered surface. Solar energy is received by the earth's surface in several forms. Although it is lost through several mechanisms, it eventually leaves through our atmosphere as infra-red heat radiation. One of the work functions on the earth's surface is the heating and cooling of our environment.

Note on Communities and Ecosystems

The scientific method requires that the object of study be identified and defined, sually at the level of the most basic sub-unit. In ecology, the basic sub-units are the ndividual species and the definable assemblages of species frequently called communities. he notion of the community, however, encompasses only the biological components of the ocality in question with little objective regard for the physical environment and important ife process of self-maintenance for the purpose of survival. The ecosystem concept conveys he ideas of functions and processes which include all living and non-living components and he physical environment. While the ecosystem concept encompasses the concept of the comunity, the reverse is not necessarily true. The term community will be used to describe roups of plants and animals as biological assemblages or units which may be easily recogized because of characteristic species or overall appearance. The term ecosystem will be sed when the total biological (biotice) and non-biological (abiotic) environment is refered to as a functional system. Whereas the term ecosystem may be used as a substitute for ommunity in the text, the reverse substitution will not often be used.

rimary Producers: Their Products and Consumers

Plants are one of the key components of both communities and ecosystems, however efined. In many terrectrial environments, they are so abundant that communities of organsms bear the name of the dominant plant species, for example, the sand pine scrub. Whereas he environmental forces help to shape the physiognomy (general appearance) of a community cosystem, plants, through their abundance, serve to modify the physical environment, partiularly the microclimate, or, community climate. The climate of a community is the climate o which a community is most intimately exposed and is therefore that portion of the climate hich most greatly influences, and is influenced by, the community. To consider these eciprocal influences compare the microclimate of a barren area with an area under forest. eneath the forest canopy, temperatures are lower, sunlight is reduced, wind velocity is ower, humidity is higher and gases tend to accumulate. More important, however, may be he fact that changes in these factors are dampened, that is, temperatures as an example re rarely as high or as low compared to a bare area of ground. Illustrated in figure 7 s a forest sketch upon which are shown the vertical environmental gradients. Note that

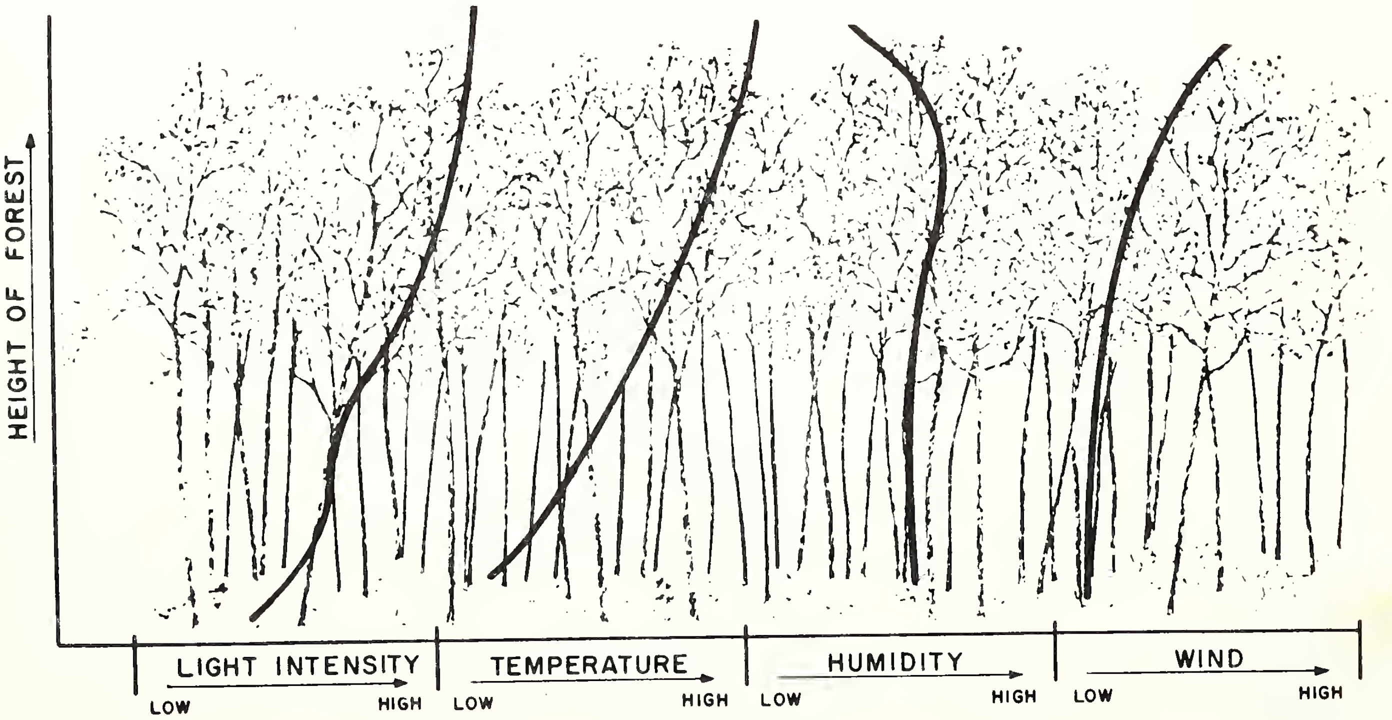


Figure 7.-Generalized vertical gradients of light intensity, temperature, humidity and wind within a forest ecosystem. Light intensity decays rapidly in the forest canopy where leaf stacking is the greatest. The light intensity measured on the ground surface is some 5-10% of that reaching the crown. Not only is the interior of a forest darker than the outside, but it is also cooler and moister. Cooling occurs through the evapotranspiration of water and the thick canopy serves as a lid preventing the moist air from escaping. Part of this results from the retardation of wind flow through the canopy or beneath. Even on windy days, the interior of a forest is comparatively still.

ach is influenced differently by the presence of the forest. The effect that vegetation ill have on the microclimate is proportional to its density. Thus a forest will have a reater influence on microclimate than will a grassland but however small the environmental odification may be, it is very important to the survival and behavior of the affected plant nd animal components. Thus, the modification of an ecosystem's microclimate, either natually or artificially, can never be under-estimated in terms of its impact on the components f that system.

Plants perform many roles important to an ecosystem, of which microclimate modification s but one. The most important role is that of assimilating solar energy and converting it o chemical energy through photosynthesis. The structure of a plant is adapted to perform his function. Photosynthesis is unique to organisms with chlorophyll - a green pigment ith the capacity to absorb radiant solar energy and to transfer the energy absorbed to iochemical reactions which convert carbon dioxide into carbohydrates. All of the numerous iochemical reactions related to the absorption of solar energy, its transfer from chlorophyll, nd its incorporation into a carbohydrate (a sugar) are thus collectively known as photoynthesis. Figure 8 details the plant structure responsible for photosynthesis and summarizes he major processes occurring within a plant system.

The products of photosynthesis contain the energy (in a chemical form) necessary to ower and maintain life in "spaceship earth". With the exception of a few bacterial rganisms which are chemosynthetic as opposed to photosynthetic, all living creatures deive their energy requirements from the photosynthetic products. Since plants and a few ther photosynthetic organisms, require solar energy to produce organic matter, it follows hat the sun powers all life on earth. The sun's role in maintaining the physical environent is discussed in Chapter V.

In the terminology of ecologists, organisms with the ability to transform solar energy nto chemical energy (stored as organic matter) are collectively called primary producers. o fill their role as producers, plants require an energy source (solar energy), energy eceptors (chlorophyll, xanthophylls, carotenoids and other pigments), carbon dioxide, ater and minerals. Through the process of photosynthesis, they give off oxygen and water nd produce organic compounds with a high energetic content. The oxygen is given off to e atmosphere through diffusion, the water is re-used by the plant and the organic materials e used to maintain the plant through respiration. The organic material remaining after e self-maintenance requirements have been met is called the net production and is availle to support those animals which feed on plants. This seemingly complex sequence is iagrammed in figure 9 in systems language using more of the symbols described in figure 2. otice how each symbol and pathway graphically describes the entire photosynthetic and espiration processes.

Respiration is the biochemically controlled breakdown of organic matter in cells ich releases the stored energy for use by the plant. As previously illustrated, resiration is the reverse of photosynthesis and therefore yields water, carbon dioxide and inerals. The products of photosynthesis power respiration, and the products of respiration, inus heat, become the raw materials of photosynthesis. The balance of nature depends on e successful coordination of these two related, but very different processes. In ecoystems, the continual circulation of raw materials (cycling) is the coupling mechanisms at links photosynthesis and respiration. The cycling of materials in an ecosystem is complished through the action of physical forces that move or circulate gases and minerals rough the biosphere, and through finely programmed and coordinated activities of producers d consumers.

The term "consumer" is used to separate those organisms that have the capacity to otosynthesize (producers) from those that do not (consumers). All consumer organisms pend on the potential energy in the chemical compounds they eat, for their growth and intenance; none can directly utilize radiant energy. Producers then, describe those ganisms which, through photosynthesis, transform solar energy into chemical energy.

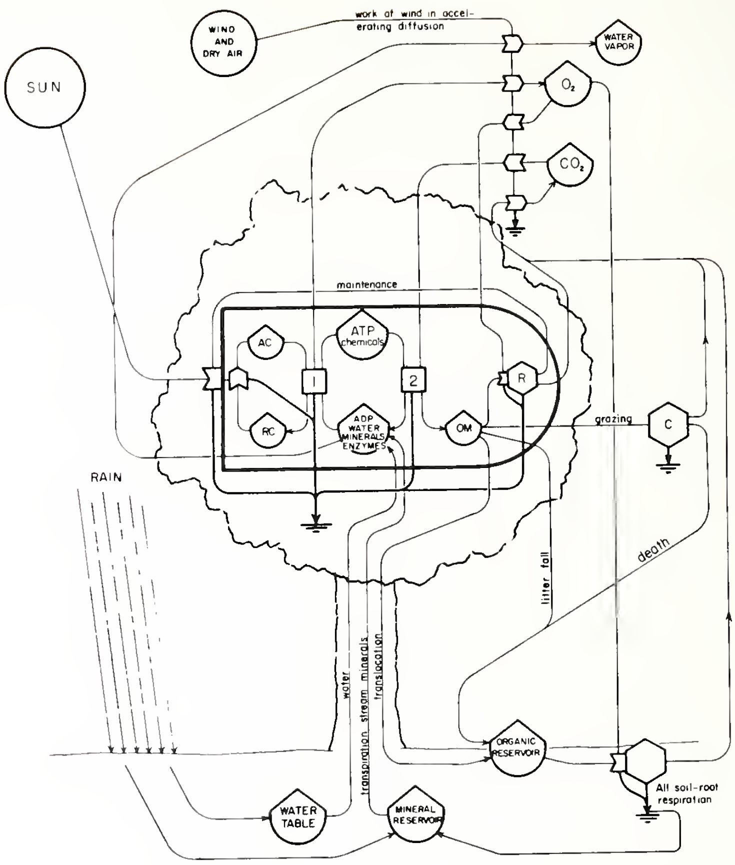


Figure 8.-The major processes within a plant system. The major forcing functions powering a plant system are sunlight, water and a combination of wind and dry air which does the work of circulating water vapor, oxygen (O_2) and carbon dioxide (CO_2). Solar energy is converted to chemical energy through the energizing of receptive chlorophyll (RC) to active chlorophyll (AC) as the initial step in photosynthesis. As (AC) reverts to (RC) the energy is used to split apart the hydrogen and oxygen of water (the oxygen is released to the atmosphere) and adenosine diphosphate (ADP) to adenosine triphosphate (ATP). The high energy ATP is used to power all subsequent biological work shown in this diagram to be the creation of organic materials (O.M.). This organic material, itself a fuel, flows to the herbivores (C), to an organic storage through translocation and litter fall, and is used to control the amplifier on overall productivity, that is, the maintenance (R) of the plant system. Both major respiratory units (R and soil-root respiration) use oxygen (O_2) and produce carbon dioxid (CO_2) and the soil-root respiration process recycles minerals back to an available pool. Water is shown entering the system through the soil water (water table) and being pumped out of the system by the drying power of the air. Each of the general processes in the diagram are closely coordinated to maintain optimum rates of energy flow.

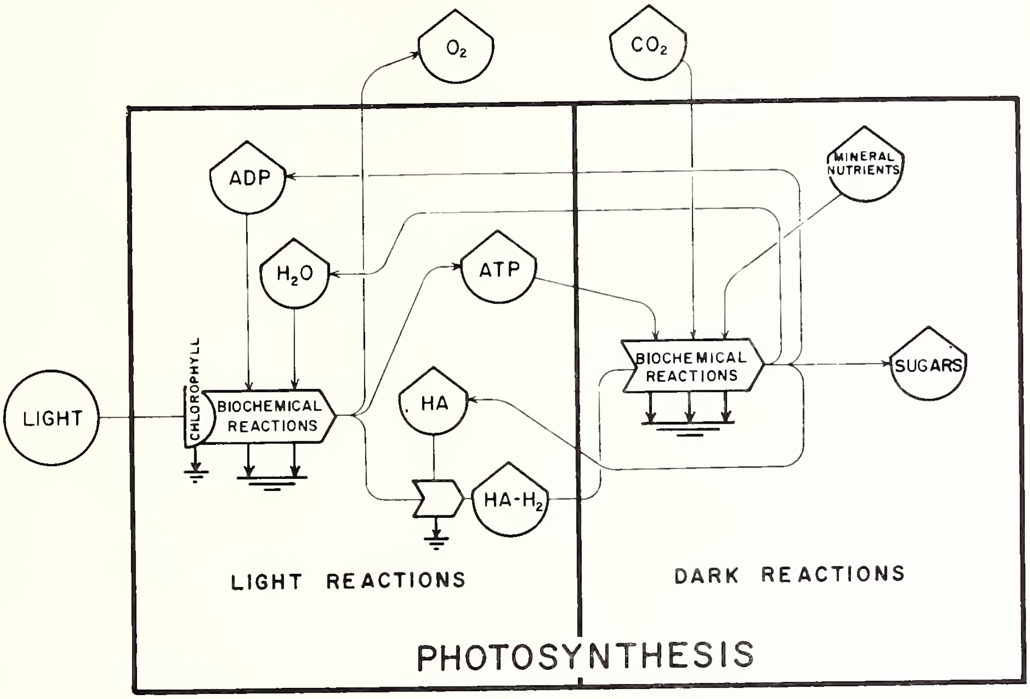


Figure 9a.-The light and dark reactions of photosynthesis. Photosynthesis may be described in terms of two sets of reactions, one of which only occurs in the presence of light and the second which may either occur in the light or dark. In the light reaction, chlorophyll is activated (energized) by light and results in water (H_2O) being broken down into hydrogen and oxygen, the latter of which is released back into the atmosphere. When sufficient carbon dioxide (CO_2) and mineral nutrients are available, a sequence of biochemical reactions converts them, along with the h hydrogen, into energy rich sugars and water. The dark reactions are powered by the reducing action of the reducing agent (HA-H_2) which is a chemical complex of hydrogen (H_2) and a hydrogen acceptor (HA). The reducing agent reduces CO_2 and minerals into sugars and some ATP is used in the process. The chemical energy originally in the HA-H_2 complex is stored as sugar until that energy is needed to power some respiratory process. The energy is actually "carried" to the process as a high energy phosphate bone in ATP. The basic molecule contains two (di-) phosphates but when energized, contains three (tri-) phosphates. Thus, when the plant requires energy to perform some work function, sugar is broken down, ADP energized to ATP and that energy is then available for immediate use.

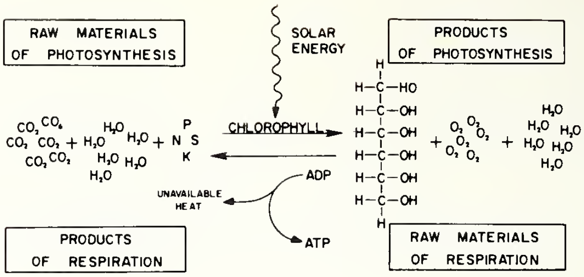


Figure 9b.-A summary of photosynthesis and respiration. Each process is essentially the reversal of the other in that the products of one become the raw materials for the other. Solar energy powers photosynthesis while the energy required for respiration is contained in the photosynthetic products. This energy is then used to do useful work utilizing ADP/ATP as the carrier mechanism. The work generates heat which is unavailable to do further work.

Consumers do not have this capacity and must depend on the energy-rich chemical products of the producers for their life-sustaining energy. This generalized sequence of events describe the dependency of consumers on the producers. Producers, however, are also dependent on consumers. Consider, for instance, a situation where producers synthesize organic materials that are never consumed. Eventually, the organic products would be accumulated to a point where there would be no room for the producers, or the system woul run out of the mineral nutrients necessary for continued organic production. Consumers prevent this by removing the "excess" production, using it to power their own growth and maintenance and in the process recycle (return) the mineral nutrients to the producers. As mentioned previously, these two processes must be precisely coordinated lest the producers over or under produce or the consumers over or under consume. This simple couplin of producers and consumers is illustrated in figure 10.

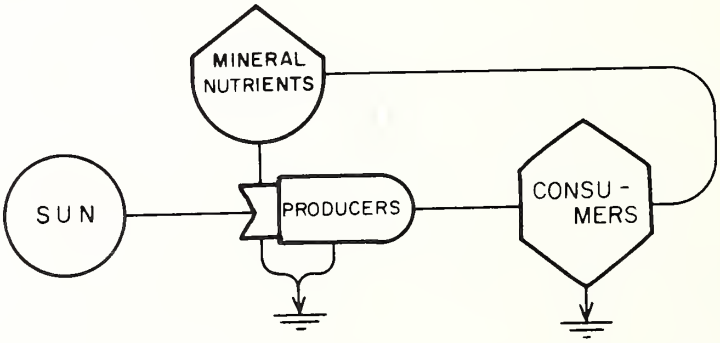


Figure 10.-The coupling of producers and consumers. Producers describe all plants which convert solar energy into chemical energy resulting in organic material (leaves, wood, fruit, roots, etc.). Consumers cannot utilize solar energy and thus are dependent on the organic production of the producers, either by eating plants (herbivores) by eating other animals (carnivores) which eat plant materials. As plant materials contain mineral nutrients, the consumers reward the plants by recycling these nutrients back to them for further use. This loop reward maintains the nutrient pool at levels adequate for continued plant growth. Note the role of the multiplier (workgate); plant growth occurs in proporation to the nutrients available.

Consumer organisms may be subdivided into several categories depending upon their feeding habits or specifically, what ecosystem components they feed upon. The consumers that feed on producers are called herbivores and those that eat herbivores are called carnivores. Top carnivores eat both herbivores and other carnivores and have no predators. More specialized terms include frugivores (fruit eaters), granivores (grain or seed eaters), insectivores (insect eaters) and omnivores (eat both plants and animals). In addition to these specialized consumers, there are other consumers whose feeding habits are more difficult to summarize. Some examples are listed:

(1) Reducers - these include fungi and bacteria which decompose dead organic matter and release minerals and gases. These are also called decomposers and are extremely important in maintaining circulation of materials in an ecosystem. An example is the microbial decomposition of leaves on a forest floor.

(2) Parasites - include organisms such as viruses, flukes, and unicellular protozoans who live and feed within a living host. Parasites aid in controlling population of hosts as they "weaken" their hosts and lower their chances of survival, particularly under crowded conditions. Even in human societies, disease and pestilence are more common in crowded areas.

(3) Scavengers - these organisms that feed on partially decayed organic matter. The vulture is such an organism.

(4) Omnivores - even though the feeding habits of this group is easy to summarize (eat plant and animal tissue), few omnivores have similar diets. They are also important because man is an omnivore as are so many of the animals in which he has a positive or negative interest, such as hogs, chickens, rats, etc.

(5) Detritivores - feed on particulate organic matter called detritus. Detritus particles are worn-out and partially decomposed bits of plants and animals. Detritivore examples include the numerous small organisms in forest floor litter and such organisms as the mullet and filter-feeders of aquatic communities. Filter feeders, like the mussel, filter large volumes of water to collect the small organic fragments.

One of the benefits of the energy language is the ease with which one can describe the interrelationship of the components of a system. In figure 11 we take each of the major categories of consumers and use the energy language to illustrate "who eats whom". Even though this generalized diagram omits much detail, it emphasizes how biological components interact within the context of an ecosystem.

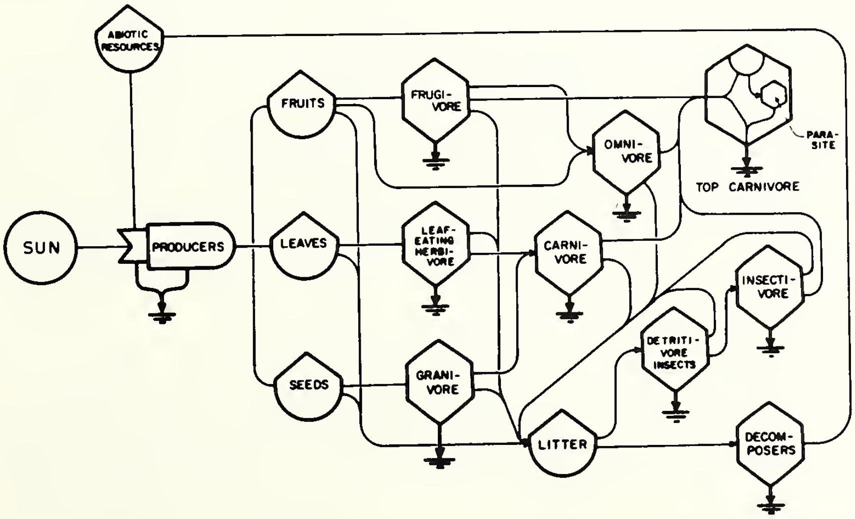


Figure 11.-The producers and specialized consumers in a typical ecosystem. Consumer categories are based on what or whom each consumer eats. This diagram relates the various categories to one another and describes the pathways along which energy flows in an ecosystem. This expansion of detail illustrates the major role of decomposers in recycling mineral nutrients back to the producers.

Food Chains and Food Webs

As food is transferred from organism to organism, a chain of organisms may be describe in which each succeeding organism is dependent on the preceeding organisms in the chain. Such chains are called food chains and each link in the chain is known as a trophic (food) level. A specific chain is shown in figure 12. When components of differing specified foo chains interact, a food web is created such as is exampled in figure 13. Figure 11, previously discussed, is also an example of a food web.

Food chains and food webs are the biological pathways within ecosystems along which energy flows. Thus, they are analogous to electrical circuits in which energy and matter simulate the flow of electricity. As analogs, the organisms at each trophic level represen capacitors and transformers. To introduce the concept of analogs, figure 12 has been diagrammed as an electrical circuit as shown in figure 14.

Fodd webs serve as an energy transfer network along which the potential energy fixed by photosynthesis is distributed through an ecosystem. The biological components receiving the energy transfers, use it to perform various work functions and store the remainder. Th stored portion is potential energy which is available for use by other components in the energy network or food web. Since a much larger proportion of the energy is used at each trophic level for the work of maintenance than is stored, the amount available for transfer to the next trophic level decreases throughout the food chain. For general purposes, transfer efficiency may be considered to be 10 per cent of the energy received. Thus, the amount of available energy is highest at the beginning of each food chain and lowest at the highest trophic levels. This progressive reduction in the amount of energy available to ea succeeding trophic level limits the sizes of populations which can be supported at the end of the chain even though the numbers of species may be large in comparison (figure 15). Observe the relative abundances of producers (green plants), herbivores (rabbits, squirrels porcupines, mice insects) and the top carnivores (foxes, eagles, bobcats and shrews). Plants are obviously the most abundant whereas few of the top carnivores may be observed.

The energy used for growth and maintenance is made available in the process of respiration which is the dominant process along a food chain. Figure 9 illustrates the coupling of photosynthesis and respiration. In a food chain this may be visualized as a progressiv breakdown of organic matter (energy rich organic compounds) that was originally organized and created by the producers at the first trophic level. In this context, photosynthesis is the process which uses solar energy to organize matter and respiration is the process which disorganizes matter and harnesses the potential energy stored during organization.

There are two basic types of food chains common to most ecosystems. These are the grazing (herbivore) food chain and the decomposer food chain. Each chain has its origin in the products of photosynthesis. The grazing food chain is based on the grazing activities of living plant material by herbivores, but the detritus chain, however, is based on the plant material not taken by herbivores and which dies and falls to the ground. An example is the litter (worn-out plant parts such as leaves, wood, flowers, etc.) which

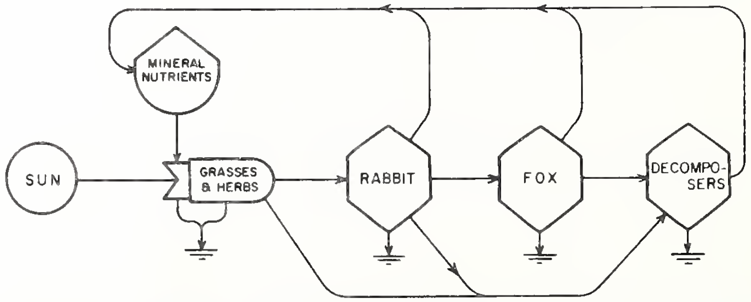


Figure 12.-A simple food chain. This sequence illustrates the flow of energy through consecutive trophic levels in a food chain. In addition to the flow of energy, note how each component also contributes to the maintenance of the system's nutrient pool.

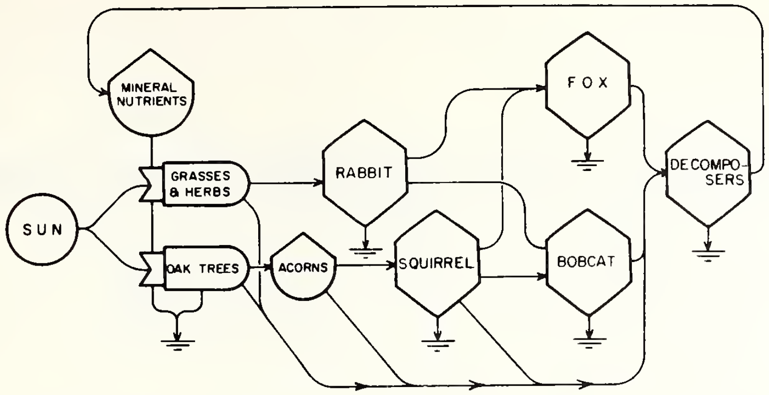


Figure 13.-Two simple food chains linked into a simple food web. Although a highly simplified example, the rabbit-fox chain and a squirrel-bobcat chain may be linked into a food web. Note how the linkages occur through the carnivores (rabbit-eating foxes and squirrel-eating bobcats) and the decomposers.

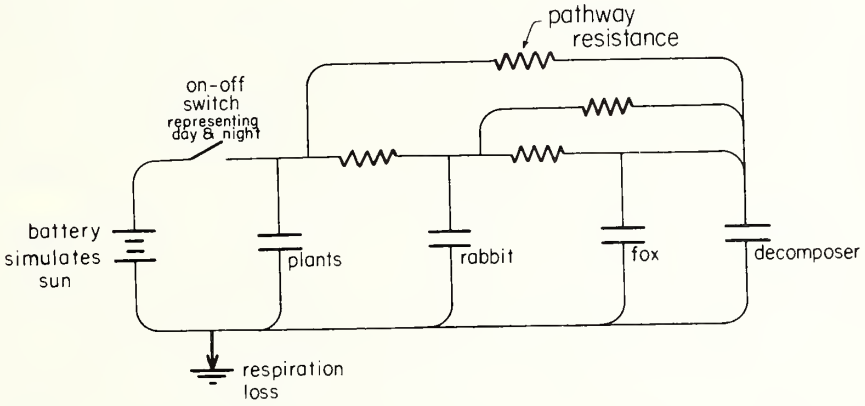


Figure 14.-A simple food chain (figure 12) diagrammed as an electrical circuit. This figure depicts the flow of carbon through a food chain utilizing electrical language as an analog of the ecological flows of the several trophic levels. Most of the electrical symbols are explained in the figure but briefly, for instance, the battery represents the sun which provides energy to power the food chain. In the diagram electrons from the battery represent this flow. A switch controlling the electrical flow (ON and OFF) represents the day and night availability of solar energy. Each trophic level is illustrated with a condensor symbol. A condensor stores electrons and the capacity to store electrons is analogous to the capacity of the trophic level to store carbon or potential energy. As energy flows through the food chains there is a progressive loss associated with respiration and entropy loss. These are simulated by the heat sink from each trophic level and the pathway resistances between trophic levels, respectively. An analog such as the one described may be constructed by the reader if he has resistors, condensors, a battery, a switch, and sufficient wire to construct the system of interest. If a micro-ampere meter is available it can be wired to any pathway to actually measure the flows between compartments and these in turn may be scaled by altering the storage capacity of the condensor, the size of the battery, or the resistances along the pathways.

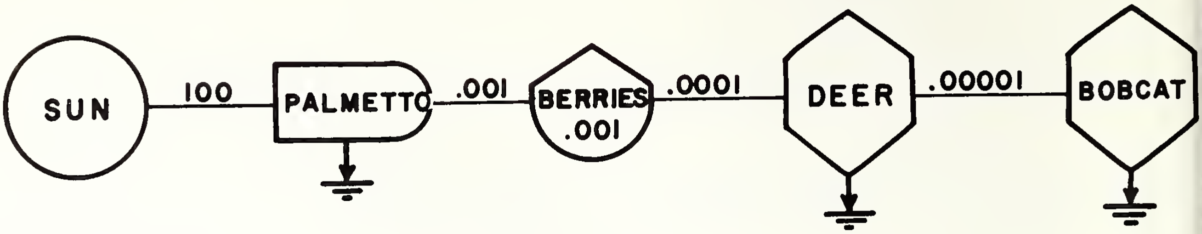


Figure 15.-Energy loss along a food chain. The sequence shows the relative proportions of energy stored, respired and transferred at each trophic level. The values suggest proportions only and may be in any energy unit such as B.T.U.'s, calories, etc.

falls from a forest. On the floor of a forest these plant fragments are progressively broken down into smaller and smaller particles by the numerous small organisms (insects, worms, and decomposers) which live in the soil. During this decomposition process, fungi and bacteria, which aid in the process, become attached to the organic particles. Their activities enrich the particles with animal protein which become minute packages, rich in potential energy, and are a food source for many small forest floor organisms such as earthworms and various insects. These consumers are the food source of such larger consumers as the armadillo whose diet consists almost exclusively of numerous small insects.

The detritus food chain is extremely important in water bodies where terrestrial and aquatic plants provide the organic substrate for decomposition. Here the enriched particles are food sources for organisms such as filter feeders, isopods and copepods and larger organisms such as scavenging snails, crayfish and catfish. The process is energy sources for numerous consumers. The forest visitor may look for indices of the decomposition process in terrestrial and aquatic ecosystems. The best example is the decomposing leaf on the forest floor and the bottom of a shallow pond or stream. The degradation stages of a leaf are illustrated in figure 16. Look for these and remember that as the leaf particles further decompose they become enriched in animal protein (figure 17).

The importance of the detritus food chains in the maintenance of an ecosystem is seldom recognized. In forests, approximately 80-90 per cent of the energy flow occurs through the detritus based food web. In aquatic ecosystems, such as estuaries or swamps rich in nutrients, it may be as high as 95 per cent. Despite the importance, renewable-resource managers are only beginning to understand this food chain, which theoretically, could be of great benefit to man as a form of production of animal protein. Presently, the bulk of man's protein is derived from the grazer food chain and its best known exampl is pastures and cattle.

The forest visitor is seldom able to recognize detrital storages in an ecosystem except for the more obvious forest floor litter. The following is a list of others which you should try to find:

(1) An old bird nest - unless the nest is maintained it will eventually break apart into smaller and smaller pieces and enter a detritus-decomposer web.
(2) Decaying leaves and twigs in the crotch of a tree.
(3) Standing dead trees and logs on the ground.
(4) Dead tree branches and the small fragments tangled in Spanish moss.
(5) The carcass of a dead animal.

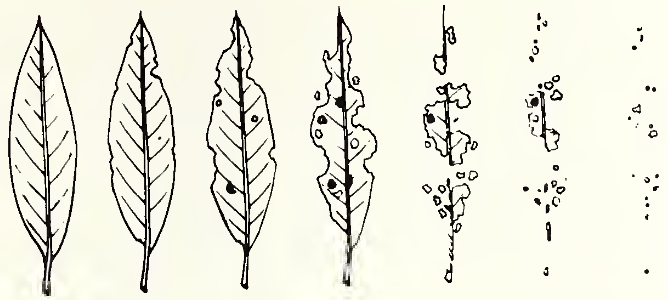


Figure 16.-The decomposition of a leaf in an aquatic environment. Through the combined actions of small invertebrates and microbial organisms, a leaf is rapidly broken down into smaller and smaller fragments. It is through processes of this type that the decomposers obtain their energy. In doing so, they are cycling the nutrients incorporated in the plant tissues. (based on Heald, 1970).

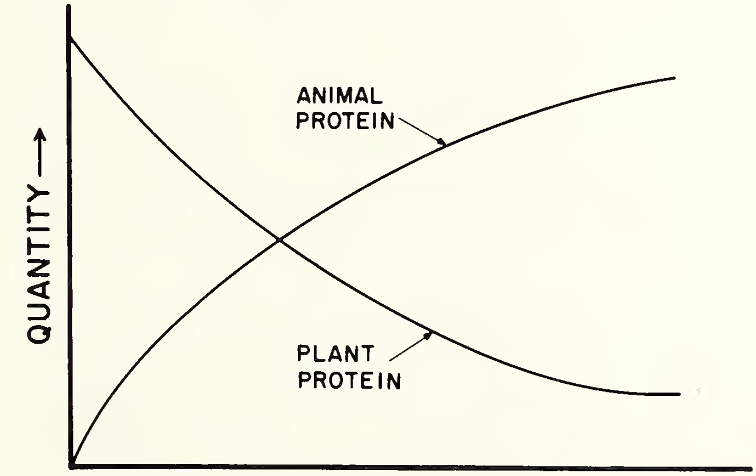


Figure 17.-The changing composition of decomposing leaf particles. Microbial decomposers are attached to the materials they decompose. In doing so, the animal protein content of the particle increases (in the microbial organisms) while the plant protein content decreases. The enriched particles are food for other important organisms. (based on Heald, 1970).

The Gross Structure of Communities

The physiognomy of a community refers to its overall structure and physical appearanc The appearance of different groupings and assemblages of species takes many forms and are expressed as forests, grasslands, scrubs, etc. The physiognomy of a community is not a random accident of nature, rather it represents the integrated results of all of the interactions between the physical environment and life processes. By studying such communi organization we may learn much, since the structure is responsive to environmental conditio i.e., structure can be interpreted in terms of its function. An example of this is illustrated in figure 18 which shows three conditions, but different communities and their respective gross structures. The important structural components such as the canopy, growth form and spacing (density) are shown. Each may be considered a homogeneous community. An ecosystem, however, may include a portion of a community, an entire community or may be defined to include all three.

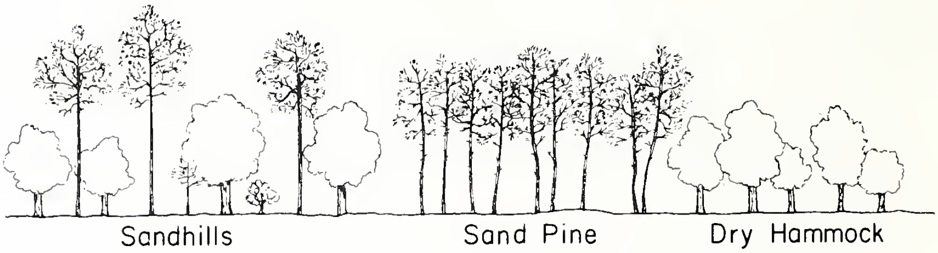


Figure 18.-The gross structural appearance (physiognomy) of three forest communities. One may learn to recognize the various communities by learning the differences in their overall appearance. The sandhills are dominated by longleaf pine and a species of oak, usually turkey oak. The sand pine communities are exclusively sand pine trees in solid stands. Note the difference in stature of the two pines and the straight versus crooked tree trunks. A dry, or xeric, hammock is composed almost entirely of oaks and other hardwoods. These three communities may be observed in the same general areas of the forest. Whereas we speak of communities, any portion or all of this diagram could be considered an ecosystem.

In most instances the environmental forces which contribute to shaping the structure of a community are not always apparent. Consider, however, a situation which is commonly seen in the Ocala National Forest and which examples a structure responding to an environmental force. Look for a stand of trees adjacent to an area in which the trees have been removed through harvesting. The exposed side of the remaining forest has developed foliage in response to the now-available sunlight. Were the existing situation permitted to continue, a community would develop on the cutover area and its canopy would eventually be coincident with the existing canopy. The lateral foliage would therefore disappear. In areas very recently harvested, the forest is only beginning to create new photosynthetic surfaces in response to the available light.

The groupings of species to communities with recognizable shapes and structures result in a mozaic of different community types distributed over the landscape. Where any two different communities meet, an area of transition may be observed. This is called an ecotone. Figure 19 shows two types of contrasting ecotones: gradual and abrupt. The sample o the abrupt ecotone is the sharp boundary sometimes observed between sandhills and the sand pine scrub. Such a discrete boundary, however, does not exist between two forest communities like adjacent hydric (wet) and mesic (moist) hammocks. Regardless of the size characteristics of the ecotone, the flows of minerals, water, animals, energy, etc., are not altered by the apparent boundary. Thus, in terms of matter and energy flow, the apparent boundaries among communities are non-functional. That is to say, adjacent communities are related one to another by mechanisms of energy and matter exchange. This inter-community relationship is covered more thoroughly in Chapter VIII.

The ecosystem concept conveys the idea of function and dynamics and expresses the fact that an ecosystem is the sum total of energy pathways within an area. Similar to any plant or animal, it consists of parts which function as an integrated unit and includes all relationships among living (biotic) and non-living (abiotic) entities and the environment. While this concept encompasses the idea of the community, the opposite is not true. For the most part, thinking about communities restricts us to the biotic and excludes the physical environment, except as it may contribute to determining the component composition and possible interactions.

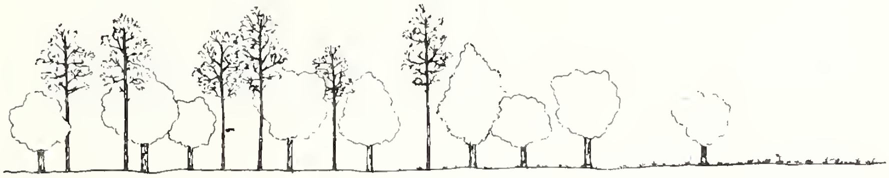


Figure 19.-Ecotones: gradual and abrupt. An ecotone is the transition area linking two ecosystem types. They may be either wide or narrow depending upon the local circumstances. In the preceeding figure (18) the ecotones are illustrated as being abrupt; the distances between either of the two adjoining are narrow and there is no integradation of species between them. In this illustration, the ecotone is so wide that only the presence of trees per se distinguishes one community from the other. The best example of an abrupt ecotone on the Ocala National Forest occurs between the sand pine scrub and the longleaf pine-turkey oak sandhills. Watch for it and should you discover a wide ecotone between these two communities, ask yourself who is invading whom. Gradual ecotones may be observed all along the eastern rim of the Oklawaha River basin. Try to discover for yourself where the mesophytic hardwood forest stops and any adjoining community begins.

The Flow of Energy and Population Dynamics

Earlier in figure 14, we compared the flow of energy through a food web with the flow of electrons through an identical network. All systems through which energy, matter and information flow become increasingly complex as the number and kind of components and their interrelationships increase. The complexity of food webs in ecosystems is a function of the species diversity of that system. Some ecosystems have characteristically simple food chains without much interaction among them. Hypersaline ecosystems (systems in a salty environment, such as an evaporating tide pool) have simple, well-insulated food chains. In other systems, the pattern of energy flow is exceedingly complex, in part, due to a greater diversity of organisms.

With respect to the diversity of organisms, the Ocala National Forest contains system with low diversities (prairies, the sand pine communities and the sandhills of longleaf pine and turkey oak) and systems with very high diversities (the mesophytic hammocks and the swamp forests). Man has a good intuitive eye for diversity and is usually drawn to those systems in an area with the highest. As you explore the Ocala National Forest consider which of the above groupings you feel, or would feel the most comfortable in hiking, camping or just being. The majority will invariably choose the more diverse irrespective of the specific reason given.

Before the topic of this section is explored, it may be best to show how diversity leads to greater functional complexity and the increased stability of an ecosystem. If one begins drawing small circles on a sheet of paper to represent individual species and then connects each circle with lines to represent possible interrelationships among species, the task suddenly becomes complex. Each subsequent addition of a circle requires numerous lines to relate it with all other circles. By increasing the number of circles (i.e., the diversity of species) the resultant network becomes increasingly complex (figur 20). The number of species in an ecosystem is much larger than the number we are able to draw and link on a sheet of paper and each is not directly related to all other species. Nevertheless, the complexity of a system's network is almost incomprehensible due to the large diversity of species and the myriad of relationships they exhibit (see Chapter VIII)

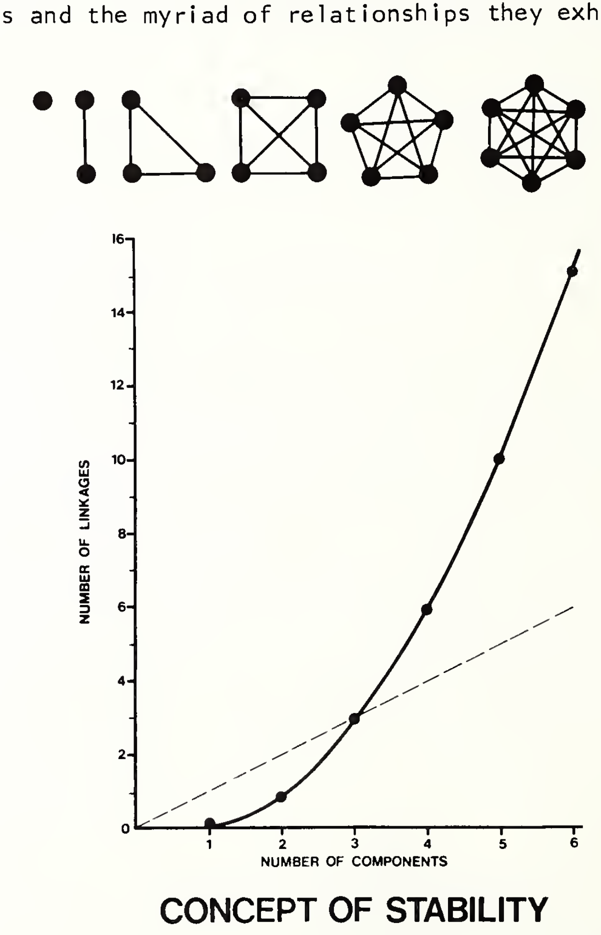


Figure 20.-Diversity and the interrelationships of components. As the number of components increase by one, the number of potential interrelationships increase by an exponent greater than one. The dotted line shows a comparative one to one relationship.

The lines or linkages in our pictorial system of species circles represent pathways f energy or matter flow. In a system of say three species, the disruption of one link r elimination of one species seriously alters the function of that system. In a diverse, nd thus complex ecosystem, a break in one link or loss of a single species may only lightly alter the system's function. Thus, diversity in an ecological system provides hat system with a higher degree of stability. Consider, for instance, the effect of liminating one dominant component species in the sand pine forest versus the mature mixed ardwood forest ecosystem. The sand pine forest would disappear whereas there would be any species left in the hardwood hammock.

In a diverse and complex ecosystem, the higher number of species results in many pecies feeding on one common prey, i.e., the food chains are interlocked to create a food eb (figures 11 and 13). The coral reef and the tropical rain forest provide excellent xamples of complex food webs. Most of the ecosystems in Florida fall between the two xtremes in diversity and complexity. For example, in the Ocala National Forest, the sand- ills and scrub communities have low diversities of species while the hardwood hammock xhibits the highest diversity.

When an individual species is studied, one may wonder how its own structural (morpho- ogical) and functional (physiological) adaptations make possible continued survival under atural pressures of predators, disease, fluctuating food supplies and the sundry environ- ental stresses. A successful species in an ecosystem is one who maximizes the flow of nergy through its trophic level (figure 21) and is the one selected for in both succession nd evolution. Energy flow is maximized by efficiently and rapidly taking energy from lower trophic level and using it to do work and then passing a portion along to a higher rophic level. Thus, success may be equated to the ability to eat and be eaten or with the bility to do useful work for the system. While being eaten is detrimental to an individual, is loss is not necessarily detrimental to the population of which he is a member. Pre- ation accelerates the flow of energy through food chains and therefore accelerates primary roduction and mineral cycling within the ecosystem. Predation is also one natural mech- nism responsible for maintaining population sizes and age distribution at the optimal evel for fulfilling a species energetic role in the system.

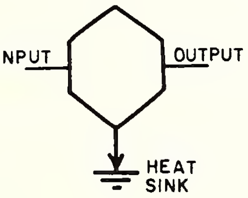


Figure 21.-Energy flow through a consumer. A consumer eats (input) and is eaten (output). Maximizing both the input and output accelerates the flow of energy through that trophic level.

The size of a population is extremely critical in energy flow. If the population ncreases in size due to abundant food or reduced predation, it will eventually exhaust the ood supply or become an easy target for various predators who then have an abundant food esource and can expand in number. Whereas energy flow may be momentarily stimulated, the opulation eventually drastically decreases to very low numbers due to starvation and/or eavy predation. Energy flow is thus significantly reduced. Seldom does the wild oscil- ation of high flow coupled with low flow equal the flow through a population whose size emains relatively constant over time. There are examples, however, where this type of scillating flow is a normal pattern, and therefore beneficial to an ecosystem because it ontributes to the survival of that system (see Chapter VIII).

The age structure of a population (figure 22) represents the number of individuals of specified age classes within a population. Naturally occurring populations are not even-aged like many of man's domesticated plant and animal populations. Instead, natural populations have members of different ages, each age-class group comprising of specific proportion of the total population. At the population level, each age class has different functions with regard to reproduction, survival, and the demand they exert on the natural resource of the ecosystem. On the left-hand side of figure 22 is a population whose age-class distribution we will call the norm for that species. Note that there are sufficient numbers of young individuals to maintain the overall population size. In the event this population experienced some problem associated with reproduction, such as destruction or loss of nesting sites, few young would be produced. The resulting age-class distribution may then appear as shown on the right-hand side of figure 22. If this were a species which required numerous young to perpetuate the normal population size, we would suspect the population to enter into a decline unless the cause of the reproductive failure was correctec

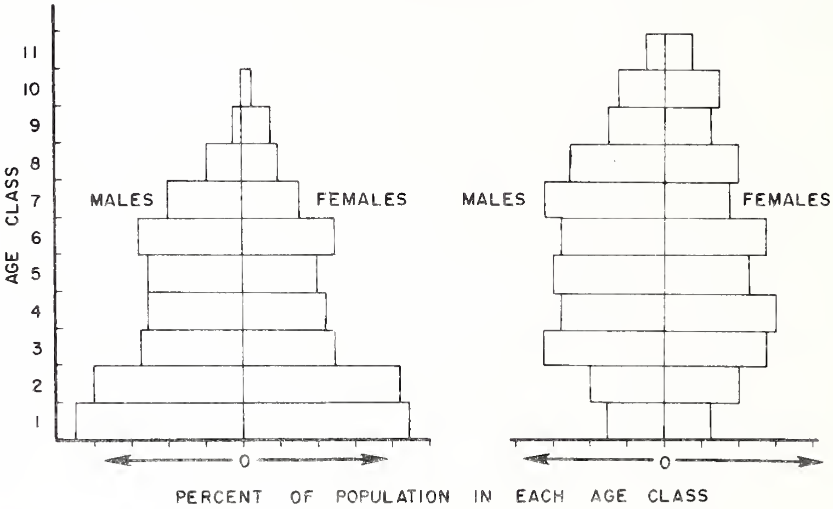


Figure 22.-Age-class distributions. The "normal" species population is represented (left) along with its appearance during the initial stage of reproductive failure (right).

Many factors affect population sizes and age-class distributions. The effects of these factors are reflected in the characteristic survivorship curves (figure 23) which show that certain age-class have higher probabilities of losing members than do others. Since the size of a population in relation to its food supply is critical to its survival, those mechanisms that eliminate certain individuals in a population are as important as those which regulate the capacity to reproduce. Parasites, disease and predators all have important roles in population dynamics and perpetuation of a stable ecosystem.

A species without "enemies" may eventually dominate an area, but its success is limited in time. Its age distribution will deteriorate, food supplies will become limiting, wastes will accumulate, and eventually the environment will be so altered that support of the population is no longer possible. Only exotic weeds and animal pests are able to maintain excessively large populations at the expense of the ecosystem which support them. Consider the water hyacinths in Florida and rabbits in Australia. In both instances, introduction of the species occurred without introduction of the species population control mechanism. The long term stability of populations in nature depend upon them being part of a stable ecosystem or, at least, part of one of its food chains. Without this dependency, natural population control mechanisms, both positive and negative, cannot serve to perpetuate the population.

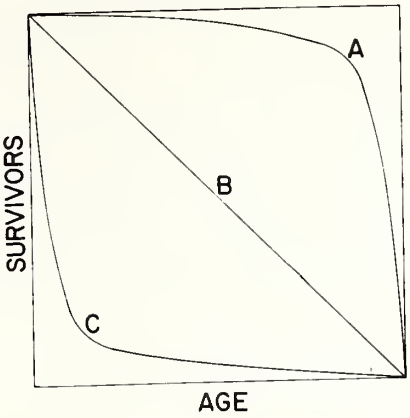


Figure 23.-Contrasting survivorship curves. Curve A shows a population which loses only the oldest individuals. Curve C represents loss only among the youngest members; an individual surviving the juvenile stage has a high probability of living to old age. Curve B shows a population which loses members evenly from each age class.

It is appropriate in this section to introduce the concept of auxiliary energy through ts relationship to the feeding behavior of consumers. It should now be apparent that for population to remain stable, it has to consume as much energy as it loses in all of its elf-maintenance processes. Likewise, a growing population must consume more energy than t loses to effect net gains. Part of the energetic cost of self-maintenance is the energy tilized in searching for food. If food is abundant; less energy is required to find it han if food happens to be scarce or generally unavailable. The amount of energy which a opulation consumes is dependent upon both the amount available and the energy required to btain it. This is illustrated in figure 24.

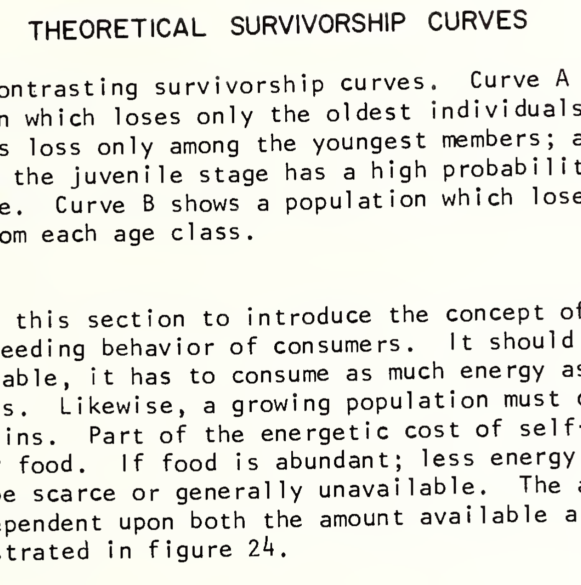


Figure 24.-The energetic cost of obtaining food. The energy flow into the predators is dependent on the number of prey available and the amount of energy necessary for searching and hunting. The workgate illustrates that as more energy is expended in hunting, the greater the flow of energy into the predators. However, as the numbers of prey drop off, more and more energy is required to operate the workgate. If the energy drain through hunting exceeds the energy obtained, there is a net loss and the number of predators decline.

Not all consumers engage in hunting and searching but rather rely on the services of nature to bring food items to them. Thus, the energy which would be required for hunting is conserved and available for other work functions. The energy utilized in bringing the items to the consumer is a form of auxiliary energy; available without an energetic cost to the consumer. Many ecosystem components and functions are adapted to utilize the energi and services provided by nature free of charge. Man would do well to begin to learn how he might also better benefit from the free services of nature. Specific examples of this one form of auxiliary energy appear in figure 25. Other examples include tides and currents which bring resources to coral reefs, rivers which transport nutrients to estuaries and the wind which brings carbon dioxide into contact with the leaves of a forest. In any given area of the Ocala National Forest, the reader should be able to identify one or several auxiliary energy sources

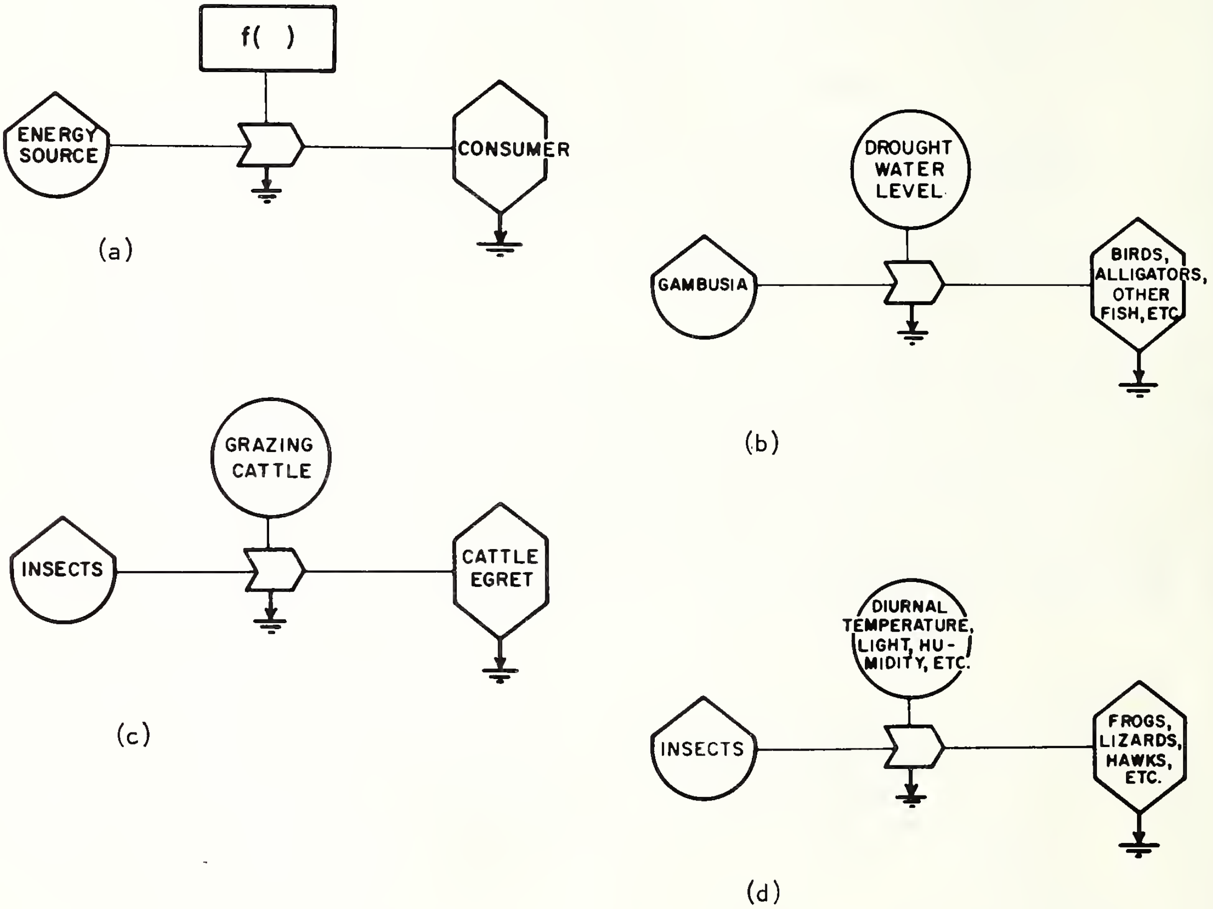

f( )
ENERGY SOURCE
CONSUMER
(a)
DROUGHT WATER LEVEL
GAMBUSIA
BIRDS, ALLIGATORS, OTHER FISH, ETC
(b)
GRAZING CATTLE
INSECTS
CATTLE EGRET
(c)
DIURNAL TEMPERATURE, LIGHT, HU-MIDITY, ETC.
INSECTS
FROGS, LIZARDS, HAWKS, ETC.
(d)

Figure 25.-The concept of auxiliary energy. (a) The major source of energy in acquiring food is supplied by an auxiliary source, identified as a function of the source. (b) Such consumers as birds, alligators, and fish prey successfully on gambusia (mosquito fish) when the water level drops and they are forced to a smaller area. (c) Cattle egrets are the white birds you may have observed following grazing cattle. The egrets eat insects flushed from grass by the activity of the cattle. (d) Many consumers sit and wait for prey to appear who become active, for instance, at daybreak or when the temperature or humidity changes. Depending on the exact circumstances the auxiliary energy may operate as a switch rather than a multiplier.

Succession: The Development of Ecosystems

The process of ecosystem development is termed succession. Ramon Margalef, a distinguished Spanish ecologist, describes succession in the following words: "Succession is viewed as the occupation of an area by organisms involved in an incessant process of action and reaction which in time results in changes in both the environment and the community, both undergoing continuous reciprocal influence and adjustment. The important point is that it is an orderly and directed change."

We have all experienced succession in some form, for instance, succession is what occurs in our backyards and forces us into afternoons of labor to keep our green lawns free of weeds. Ecologists recognize two types of succession: that occurring in areas where life has not previously existed (rocks, recently deglaciated areas, new islands), and that which occurs in areas where existing communities have been disturbed (a forest or grassland after a fire, mangroves after a hurricane, a freshly cut lawn or clear-cut harvest site). The former type is known as primary succession, and the latter as secondary succession. Since conditions are harsher for primary succession (soils are lacking, or the climate may be very dry) the rate of process is slower than that for secondary succession. Because of its rapid rate (as compared to primary succession) more data are available on the trends and mechanisms of secondary succession than on primary succession. Our discussion is based on secondary succession but the basic principles apply as well to primary succession.

A forest might appear to be static and dull to the Sunday visitor. However, if he stays long enough he will be amazed at the degree of activity and change that takes place in such systems. Branches, leaves, twigs, and even whole trees are constantly falling and being replaced by new structures. Within an apparently stable community, successional changes are occurring at all times and places however, in a stable situation succession as a form of ecosystem repair is not readily apparent. Such successional changes may be studied from the taxonomic, zoological, botanical, or ecological viewpoints or by measuring numerous parameters such as changes in soil temperatures, light transmission, and species composition. There is considerable argument as to the appropriate criteria and terminology needed to describe and understand succession. It seems apparent that succession is not a single process, but, like photosynthesis, is composed of many trends and sub-processes which result in the net effect of community change.

It is apparent that succession is related to time; that over time less mature ecosystems become more mature. If we could visualize forest succession as occurring over space we could create a representation such as is shown in figure 26. At the beginning of succession, an area is dominated by grasses and small herbs. Eventually, various woody shrub and tree species invade the area and become dominant by replacing the existing species. As the system further matures, the trees grow in size and the canopy becomes closed, shading the area beneath the crown. Those species which germinated and grew in full sunlight cannot become established in the shade of the forest and over a long period of time are lost from the system and not replaced. Some tree species, however, can germinate and become established in the shade and it is this group that eventually replace themselves. This is a climax or mature ecosystem based on its self-perpetuating species composition. In general, early successional plant species have survivorship curves approximating (A) in figure 23, and climax species approximating (C) in the same figure.

Ecosystem development or the maturation process of succession can be described in many ways in addition to species composition and gross structure. Ecosystem characteristics such as diversity, complexity, stability, biomass, net production and respiration also change during succession and thus offer additional insight into this common phenomenen. Shown in figure 27 is a generalization of the process of succession over time and how each of the listed ecosystem characteristics change with increased maturity. Note that each characteristic, except net production, increases and then levels off. Net production, however, decreases but also levels off. Margalef equates these characteristic changes

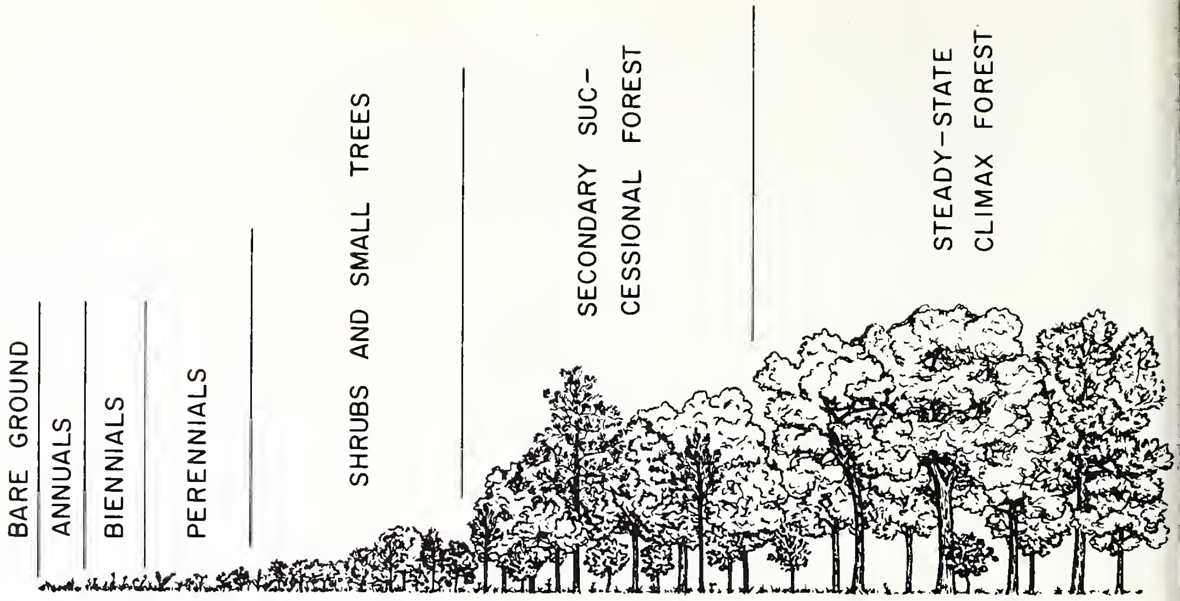


Figure 26.-A generalized scheme of ecosystem development (succession). The earliest stages are on the left and the climax is on the right. Age of the system increases from left to right.

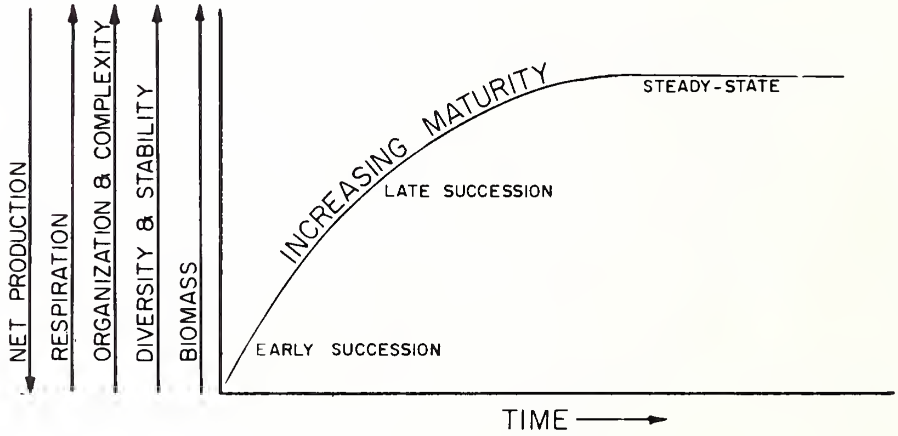


Figure 27.-Relative changes in certain ecosystem characteristics during succession. Each characteristic increases over time except net production which decreases. Compare the changes in these characteristics with the events in figure 26.

ith maturity, which is indicated as a summary characteristic on the graph. The leveling ff of each characteristic at maturity indicates that, in general, there is no further ignificant time-related change except for continual internal repair. This continuation ithout change in each characteristic is called steady-state, and thus we may call the nd point of succession a steady-state ecosystem.

Earlier we discussed organic production as a product of photosynthesis and as the nergy source which through respiration was harnessed to do the work of growth and aintenance of ecosystem components. In figure 27 we see that net production decreases hile respiration increases. For clarity let's relate production and respiration in a imple equation:

Net Production = Gross Production - Respiration
or
Gross Production = Net Production + Respiration

ross production is the total photosynthetic product created from solar energy. The energy n this organic material is used during respiration to pay the energy costs of maintenance. nly under certain circumstances (to be described) is all of the gross production used in espiration; and surplus organic production not used is called the net production. The et organic production is stored by the system in the form of new growth. We can easily hen call growth net production or that portion of the gross production which is left over fter all maintenance work has been taken care of. With this concept in mind, how could e interpret ecosystem development?

In the allocation of energy, individuals, colonies and populations, and ecosystems ust first pay the energetic cost of self-maintenance and if energy is still available, hat portion is channelled into growth. For an example of this concept (in ecosystem evelopment) we will consider the sequence of ecological events which occur when a forest s clear-cut and then burned. Immediately after burning, the total quantity of living aterial (biomass) is close to zero as only the soil micro-organisms and a few seeds and iving roots remain. Quickly, however, the area is colonized by plant species, such as rasses and herbs, which have the ability to become established on unstable areas. The nitial result is a low mantle of green vegetation reminescent of a weed patch. Gross roduction is initiated in the photosynthetic mantle and due to the low maintenance equirement of the small quantity of biomass and the simplicity of the system, most of he production is net production and contributes to new growth. Thus, the developing cosystem increases in size evidenced usually in an increase in height. The increase n biomass continues over time but eventually drops off as the maintenance requirements ncrease. (One must have in mind that a natural ecosystem is dependent upon solar energy nd that the amount of solar energy per unit area of ground is the ultimate limiting actor to productivity.) The larger more complex ecosystem expends more and more energy n respiration and the amount left over for growth progressively decreases. Eventually point is reached where all of the energy is expended in respiration and further growth eases. The ecosystem at this stage is the mature climax or steady-state system. This equence is evident in figure 27 in that our characteristics which describe a steady-tate ecosystem are at their maximum except net production. Expressed in another way, et production decreases to a point where gross production equals respiration (figure 28).

The question must inevitably arise as to why within a regional ecosystem, and also mong regional ecosystems, the examples of succession, and for that matter steady-state ystems, are so different in appearance. The first and most obvious reason is related o the variations in species composition. Depending upon the local and regional environ-ental circumstances, there are species which are better adapted than others. These will e the species which one will most frequently observe in the field (see Chapter VI for discussion of species composition and species assemblages in the Ocala National Forest). rrespective of the actual species composition, much of the structural variation among

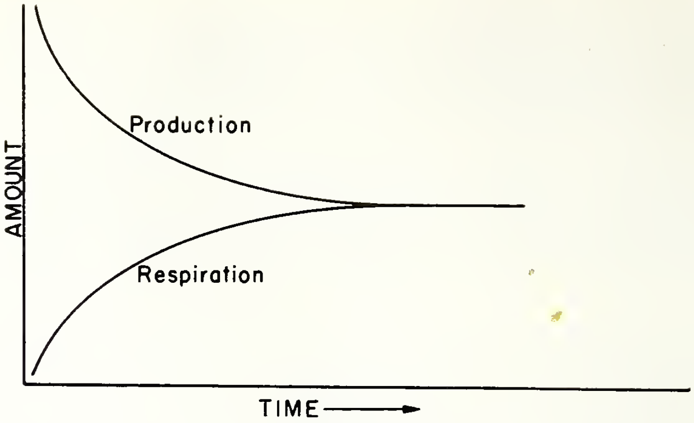


Figure 28.-The energetics of the steady-state. Both production and respiration change over time in a developing ecosystem. A steady-state is described when net production is zero and gross production equals respiration.

ecosystems relates to the allocation of energy between growth and maintenance. Maintenance includes both the normal metabolic processes associated with living organisms, plus the energy which must be expended for the repair of damaged tissues, replacement of lost tissues and for coping with environmental stresses. Stress may therefore be defined as any action or force which requires an expenditure of energy to overcome. For instance, heat is a stress at high temperature (figure 29) in that respiration increases with increasing temperature. At approximately 30° C (86.0° F), respiration equals the product output of photosynthesis and growth (accumulation of net production) ceases. This is sometimes called the compensation point. At over 30° C, the respiratory demands exceed production and plant energy reserves must be tapped to power the increased respiration. If, in this specific example (figure 29) the difference between photosynthesis and respiration is equivalent to net production, then growth decreases progressively up to about 30° C. Thereafter, the potential energy stored in biomass must be consumed.

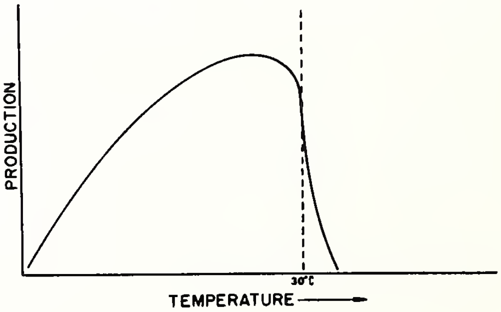
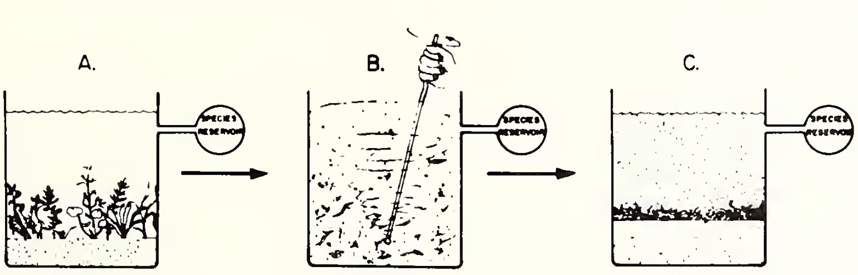


Figure 29.The relationship of temperature to photosynthesis and respiration. Photosynthesis is relatively insensitive to temperature over a range of approximately 0°-30° C. Respiration, however, is a temperature dependent process. At about 30° C, photosynthesis equals respiration and growth ceases. This is the compensation point.

To a large extent, the rate at which an ecosystem develops is dependent upon the number and intensities of the local stresses, which may include such factors as temperature (abnormally high or low), water (deficient or over abundent), low soil fertility, consumers (taking too little or too much), fire, or some activity of man. Each stress draws energy away from growth by increasing respiration and the rate of ecosystem development (succession) decreases. If the stress is chronic, i.e., the stress is reoccurring, the system does not develop a complex and large structural physiognomy, or it may remain in an early stage of succession. In nature, these systems are called arrested successions. Acute stresses, occurring as random pulses, temporarily retard succession until the ecosystem has recovered at which time further development ensues.

If a miniature replicate (a system containing producers, consumers processing energy and cycling minerals) of a natural system is studied as a laboratory microcosm (figure 30) one will see that it matures, going from the characteristics describing early stages (immature) to a climax (last stage of succession); many of the trends described in the figure 27 can be observed. If a stress is applied to the system, the degree of maturity will decrease. Increases in temperature, reduction of light intensity, increase in salinity, fire, or ionizing radiation, could be used as stresses, to which the system's reaction is always a shift in species composition leading to the elimination of those not capable of surviving the stress in favor of those that will.



Steady-state Aquatic Microcosm:	Stressed by vigorous stirring.	Successional Aquatic Microcosm:
Organized Complex Stable Low net production High respiration Many species–High diversity Few individuals per species	Reservoir remains undisturbed.	Unorganized Simple Unstable High net production Low respiration Few species–Low diversity Many individuals per species

Figure 30.-Ecosystem characteristics in a microcosm. A laboratory microcosm and reservoir (A) is filled with freshly collected pond water, sediments and micro-organisms and allowed to stand long enough to reach steady-state. This mature microcosm is stressed (B) by vigorous stirring which results in a microcosm system of lower maturity. The undisturbed reservoir represents a constant source of aquatic micro-organisms.

Only very specialized populations are capable of surviving a particular kind of stress, such as chemical pollutants, fire, low fertility or flooding. Therefore, the overall effect of the stress on the system is the reduction of species and the increase in the number of individuals of few species. However, systems which have been exposed to a particular kind of stress for a long period of time will have evolved and become adapted to the stress. Once adapted, the system may not survive without it - for example, the sand pine forests.

Natural ecosystems are subjected to many kinds, degrees, and intensities of stresses. Some examples are the daily fluctuation of tides in estuaries, the occurrence of cold and dry seasons in temperate areas, the unpredictable occurrence of hurricanes and fires in tropical and subtropical areas, and the imperceptible action of soil nutrients in limiting quantities or at toxic levels. With such a diversity of stresses, the resulting diversity of community types observed in the landscape becomes less mysterious. In areas where man has no effect, environmental conditions will arrest succession at different levels of maturity. Communities with different diversities, metabolic patterns, and developmental characteristics will result. However, as ecosystems, they maintain their interrelationships through energy, material, and gene flows across their apparent boundaries. Their species compositions are different because each is specialized to tolerate a different stress.

Man is capable of utilizing his talents and energy reservoirs to remove or add stresses, and therefore, manipulate succession. For example he may eliminate fire and add missing nutrients to the soil and therefore, increase the level of maturity of ecosystems in the area. Conversely, he can plow, fertilize, seed,and control land so that only immature systems can survive. Since these systems have high net productions, man may derive abundant food from these systems. Man, whose major interest is production, is particularly concerned with stress and its manipulation as a management tool for arresting succession. His role as a manager of succession is detailed in Chapter III and examples are scattered through the remaining chapters.

THE SYSTEMS APPROACH

Introduction

Thus far we have introduced some aspects of the environment, the biology of ecosystems, relationship networks, and a synopsis of succession. In this section we will review these topics and introduce additional material necessary for an understanding of the ecology of the Ocala National Forest. The presentation will differ in that the systems approach will be heavily emphasized to provide the reader with a framework to interpret the material presented in later chapters.

The Functioning Ecosystem

Ecosystems require energy for many different functions all related to both the short and long term survival of the system. The requirements range from the maintenance of coupled producer-consumer populations to those associated with the structural maintenance of the system. Structural maintenance includes repair or replacement of damaged or lost parts, mineral circulation, species organization, increased stability and evolution (figure 31). The primary energy source is the sun and is made available through photosynthesis. Other auxiliary energy sources (other than the energy derived from photosynthesis) are defined as energy inputs to the system which are used for some ecosystem function and thus lessen the drain through respiration (figure 25). For example, the movement of minerals in system could be accomplished by the activities of animal species (large herds of grazers or migrating fish) but this requires an energy expanditure equal to the metabolism of the species involved, plus the cost of coupling the species to the rest of the system (organization). If some outside energy source could be tapped so that the organisms did not have to perform this function, the system would then have additional energy available to accomplish some other function. Some ecosystems actually have such outside energy sources which do the mineral circulation work. Estuaries are a good example. Here, the daily tide movement fulfills the same role in circulating minerals as do migrating animals in savanna ecosystems. Wind movement, when it provides the system with air that is rich in CO_2 and low in moisture, is another example of an auxiliary energy source. This function accelerates photosynthesis and transpiration in plants and thus increases the potential energy available to the system. However, these auxiliary sources benefit the ecosystem ONLY if the ecosystem

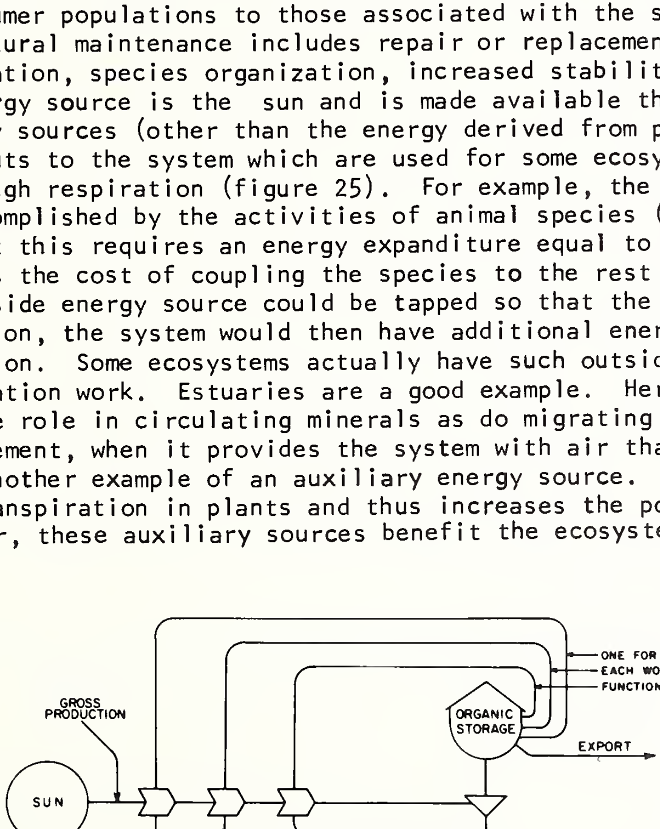


Figure 31.-The role of stored energy in an ecosystem. Stored (potential energy is used to perpetuate the system through growth and maintenance, or a portion may be exported to a coupled system. The work functions illustrated, for example, include repair or replacement of damaged or lost parts, mineral circulation, and the costs of increased stability and further evolution. Perpetuation of the system necessarily implies the maintenance of gross production. The amount of energy available for export or harvest by man is proportional to the system's gross production minus all the ecosystem work functions necessary to maintain gross production.

contains the structural adaptations that can tap them. If the system is not so adapted, these factors may actually be harmful instead of beneficial. When the proper structural adaptations are present, though, the auxiliary energy source lowers the energy demands ma on the photosynthetic processes. Tides would not be beneficial in nutrient cycling in an estuary if filter feeder organisms, like the mussel and the oyster, did not exist (mussel for instance, remove phosphorus from the water and re-deposit it on the substrate in the of fecal material where plants are able to re-use it.) Likewise, canopy structures are usually ragged (uneven) and therefore, create turbulence which helps in tapping the auxil energy associated with wind. Examples of auxiliary energy sources are given in figure 32 In the following text, we will be using the term compartment for ecosystem components, however defined, which store energy or material.

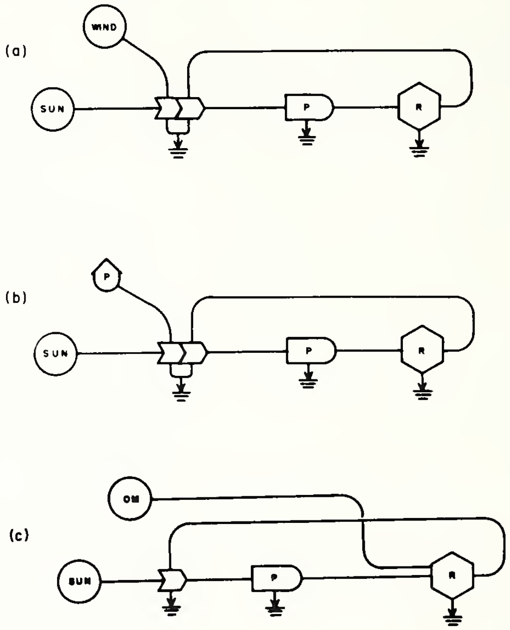


Figure 32.-Three examples of sources of auxiliary energy in a generalized producer-consumer ecosystem. In each, the sun is shown powering the producer component (P) the products of which are respired (R) in the consumer food chains. The feedback relationship of consumers on producers is shown stabilizing the system. (a) Wind moves CO_2 and dry air into a forest system. CO_2 is necessary for photosynthesis and dry air is necessary for transpiration and mineral nutrient uptake. Wind, therefore, accelerates production and the flow of energy and thus is an auxiliary energy source. (b) Phosphorus is a required mineral nutrient in all biological systems. In limiting quantities it controls energy flow; too little, limits production and the addition of phosphorus increases production, and is therefore an auxiliary source of energy. (c) The two consumer food chains, herbivores and detritivores, are supported by the parent system's production. In some instances, organic material is produced in some other system and transported into a receiving system where it is used by the component consumers. This "extra" energy supplements the photosynthetic energy of the receiving ecosystem and is therefore an auxiliary energy source. This example could be the aquatic system described on page 23 where the auxiliary energy is derived from decomposing leaves produced elsewhere.

Eventually, all of the energy that is incorporated within an ecosystem is used to do ork. Energy is the capacity to do work and is measured in calories. All of the energy xpenditures of ecosystems are related to some kind of biological work. This includes a road range of functions ranging from (for example) a fox chasing a rabbit to a tree growing ew leaves in the spring. Energy flow from an upstream compartment couples the compartment, nd, as it flows through the downstream compartment it does organizational work; the work of rowth and maintenance of ecosystems. Some of this energy however, is fed back into the pstream compartment where it is dissipated through some other work function. Such flow rom a downstream compartment into an upstream compartment is known as a feedback (figure 33). feedback is a control device and it expresses itself as energy or material flow. Feedback echanisms are sensitive to energy or matter flow between compartments and actively maintain steady flow between them. Positive feedbacks augment or increase the flow between compartments. The return of minerals to the plant compartment after bacterial decomposition r organics in the litter is an example of a positive feedback.

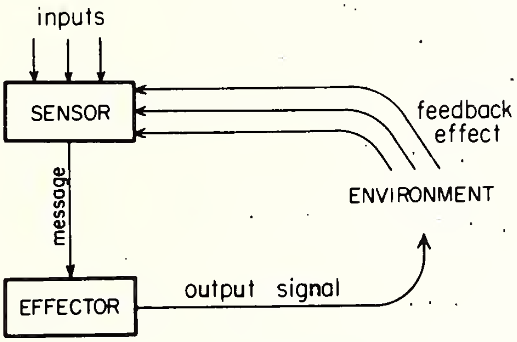


Figure 33.-Elements of the basic feedback system. The sensor receives signals from the INPUTS and activates the effector. The OUTPUT modifies an environmental factor stabilizing it around some optimal value for that ecosystem.

ineral nutrients increase the rate of photosynthesis and thus the potential flow of rganic matter into the litter compartments is increased. A negative feedback decreases he rate of flow between compartments. An example is the storage of organics in a massive torage compartment. As the storage capacity is approached, the accumulation in the tank reates a back-force which reduces the rate of inflow into the compartment. The positive nd negative feedback relationships were discussed on page 38 as they operate as controls, r stabilizers, on population sizes.

We may summarize by saying that an ecosystem is a network of compartments which comensates for environmental stresses by harnessing solar energy through photosynthesis and uxiliary energy sources through structural adaptations. Photosynthetic energy is stored in rganic matter which flows through the ecosystem's food web circuits, being stored momentarily n the various structural compartments. As energy flows through the many compartments, biogical work is done and heat is released to the environment. Feedback mechanisms regulate nergy flow and are responsible for the homeostatis or stability of an ecosystem.

The Compartments of Ecosystems

The first step in the study of any ecosystem is the identification of its compartmen (both living and non-living). Depending upon the boundaries set by the investigator, the kinds and numbers of compartments will vary. In this section, examples of living and no living compartments are discussed.

Plants are the most conspicuous component of terrestrial (land) ecosystems. They c be lumped into one compartment (the plant compartment), subdivided by species (as many co partments as there are species) or by plant parts (stems, roots, leaves, etc.). The subdivision of a compartment depends merely upon the purpose of the investigation. In figur 8, a plant system was described in terms of its structural and functional compartments.

Water, air and soil substrate are examples of non-living compartments that must be considered when sub-dividing a system into its components. They are the vital reservoirs of both materials and potential energy important to the function of ecosystems. For example, the substrate of a forest accumulates organic matter through two mechanisms; passive fall from tree canopies and active transport by animals. Figure 34 shows a profi of the forest floor. The upper layer of organic matter is known as the forest litter. This compartment maintains the detritus food chain and decomposition process essential to plant growth and system productivity.

After compartments are identified, the next step is to determine the function and interactions of the compartments. How are they related? What are the compartment sizes and the rates of flow of matter and energy? How does the compartment behave in different times of the year and under different environmental conditions? Are compartments coupled If so, how? These and many other questions are the ones that ecologists seek to answer through field and laboratory experiments. These questions will be treated next.

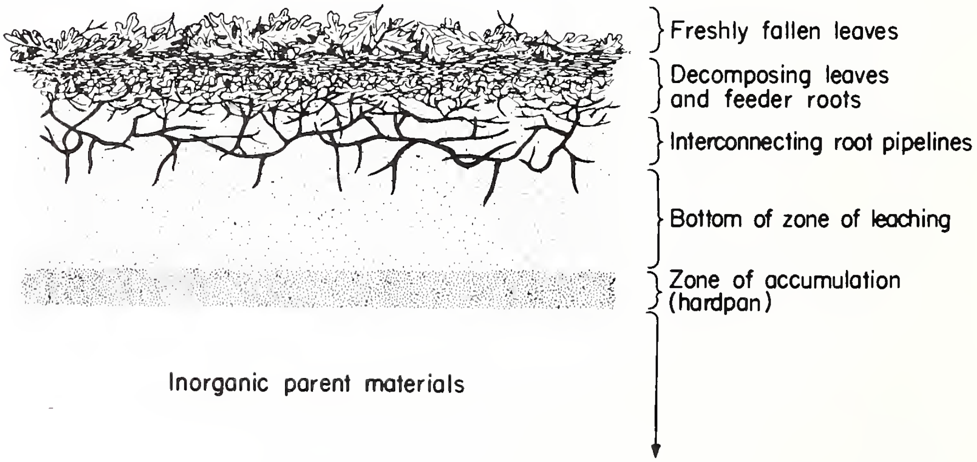

Freshly fallen leaves
Decomposing leaves and feeder roots
Interconnecting root pipelines
Bottom of zone of leaching
Zone of accumulation (hardpan)
Inorganic parent materials

Figure 34.-Litter decomposition and root structure; profile view showing the litter compartment, the root structure and soil in a forest ecosystem. The upper layer of leaves, freshly fallen have not begun being decomposed. The bottom leaves are rapidly being broken down and decomposed and are in contact with the small, feeder roots of the root system. These feeder roots serve as collection devices for the organic and inorganic products of decomposition which are transported by the larger pipeline roots below them. The importance of this subsystem function to the ecosystems of the Ocala National Forest is discussed in Chapter VIII.

he Behavior of Compartments

Each compartment is characterized by an input, an output, and the storage of energy r essential element(s) (figure 35). These characteristics are sensitive to environmental onditions and the net effect of differences in input-output rates results in two related haracteristics of compartments, the turnover rates and the residence time. The turnover ate is that fraction of the total amount of a substance in a compartment which is released or enters) in a given length of time. Residence time is a measure of how long a subtance is retained in a compartment before it is released. Its units are given in seconds, inutes, hours, days, years or centuries depending on the size and turnover rate of the ompartment. The equations on the next page describe the relations involved in calculating urnover rate and residence time.

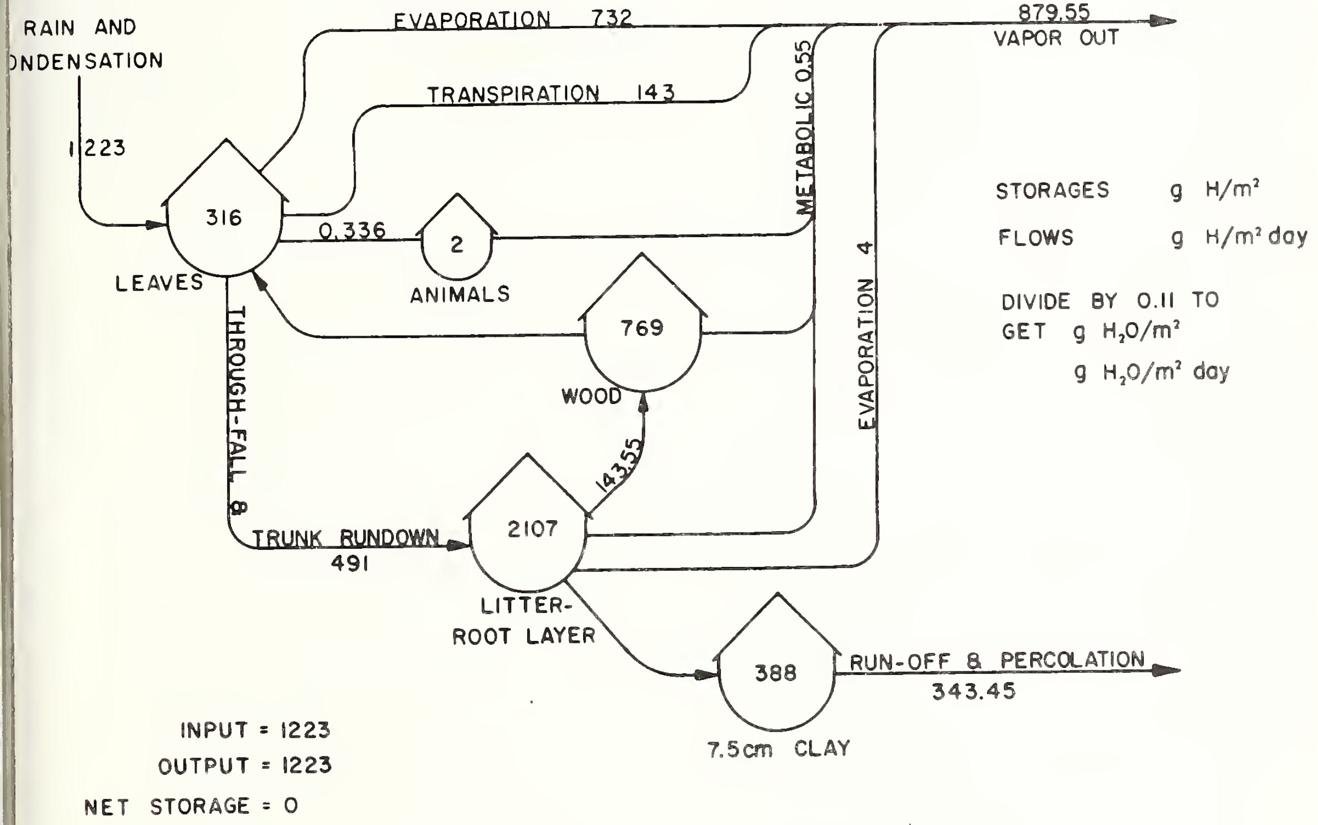


Figure 35.-The movement of hydrogen through a rain forest. For the purpose of illustrating flow only the storage and flow symbols are used. The rain forest example (Puerto Rico - El Yungue) received water from both rain and condensation on the leaf canopy. Of this total input some 18% flows down the stems and 56% falls directly to the forest floor. The remainder (26%) is evaporated directly from the canopy. Evaporation also occurs from the surfaces of many of the system's components as illustrated leading to "vapor out" in the upper right-hand portion of the diagram. Other losses from the system occur through surface and sub-surface (percolation) runoff and transpiration. The transpiration stream is illustrated. Water is also transferred among components and lost through respiration where it may be either re-cycled or lost as vapor. Whereas hydrogen moves through this sytem in relatively large quantities, the net storage is zero. To determine the actual water flow and storage, divide each value by 0.11. (from Odum, 1970).

$$\text{Turnover rate} = \frac{\text{rate of input or output (in g/m}^2\text{/hr)}}{\text{storage capacity (in g/m}^2\text{)}}$$

$$\text{Residence time} = \frac{\text{storage capacity (in g/m}^2\text{)}}{\text{rate of input or output (in g/m}^2\text{/hr)}}$$

You will notice that one is the reciprocal of the other, that is, either answer divided into 1.0 will yield the other answer. The importance of these calculations to the understanding of matter and energy flow cannot be over-emphasized. Figure 35 is an example using the movement of hydrogen through a rain forest. If either by accident or design, radioactive hydrogen (tritium) was released in such a forest ecosystem, it would be to th advantage of man to know where this material was being concentrated because tritium quick replaces normal hydrogen and can enter the biosphere through the water cycle. By calculating (1) the turnover rates of the compartments shown, and (2) the residence time of tritium in each compartment, one can determine where the isotope will concentrate (i.e., wood, leaves, ground water, etc.) and then plan a method for its removal if such is possible. Similar calculations allow ecologists to deal with such problems as tracing the movement of DDT through ecosystems (figure 36), or fertilizers or mineral nutrients withi

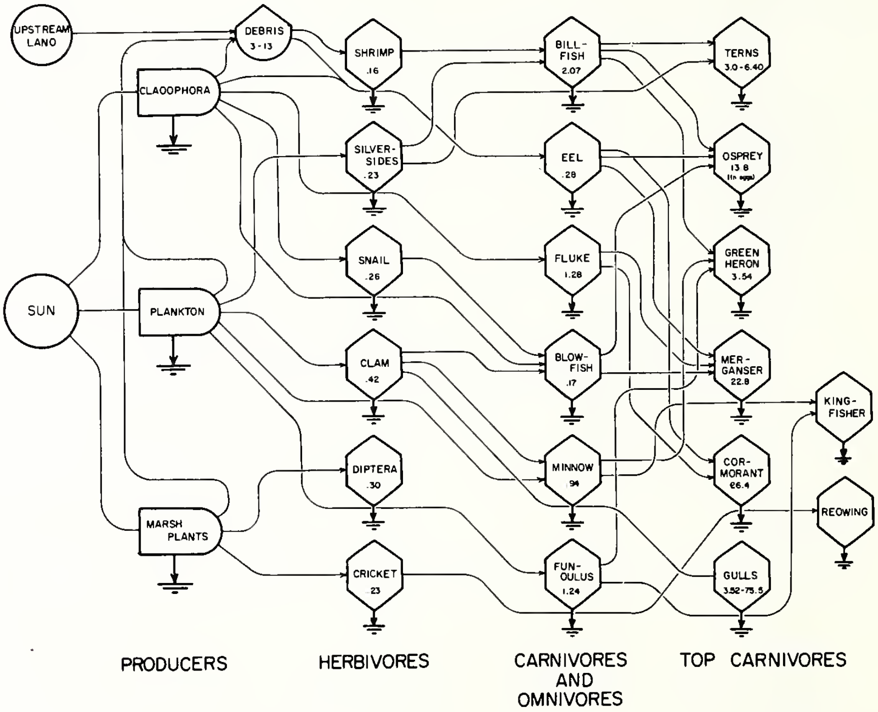


Figure 36.-The movement of DDT through an ecosystem. The pesticide DDT is soluble (i.e., dissolves in) in fat, insoluble in water, and is resistent to degradation. A common pathway for DDT to enter aquatic environments is through direct application or through absorption on detrital debris. Small aquatic organisms ingest these particles and the DDT is incorporated in their body fat. As each organisms is consumed, its body burden of DDT is passed along to the consumer where it is also stored in the body fat. Because DDT is not lost within the food web, it becomes concentrated in the top carnivores. The figures represent the relative amounts of DDT in the components of an ecosystem. The flow lines represent energy flow through the trophic levels and do not necessarily coincide with DDT. Note that body burdens of DDT vary among organisms within trophic levels. (from Woodwell, 1967).

nd among forest ecosystems. Such practical problems can be solved only if ecologists have ata pertinent to the understanding of flow dynamics through ecosystem compartments. We ust learn to predict the behavior of the various compartments under changing environmental onditions and in different ecosystem types. Let's now consider some of the gross behavioral haracteristics of selected forest compartments.

If we visualize a forest ecosystem as a complicated network of storage compartments, ach with its own characteristic input and output functions, one would expect the timing of nputs and output from related compartments to be the critical factor in maintaining the tability of the system. For example, if a storage compartment, such as litter, released ts nutrients during the rainy season, and another compartment was not available to store hese nutrients, the system would lose valuable minerals to the water runoff and thus reduce ts future capacity to produce organic matter through photosynthesis. The timing of nutrient elease through decomposition and nutrient uptake for photosynthesis is thus critical to cosystem productivity. Working with granite outcrops in the Piedmont of North Carolina, cologists have found that a large portion of the biomass which died at the end of the growng season (September), remained standing during the rest of the fall and winter. Little

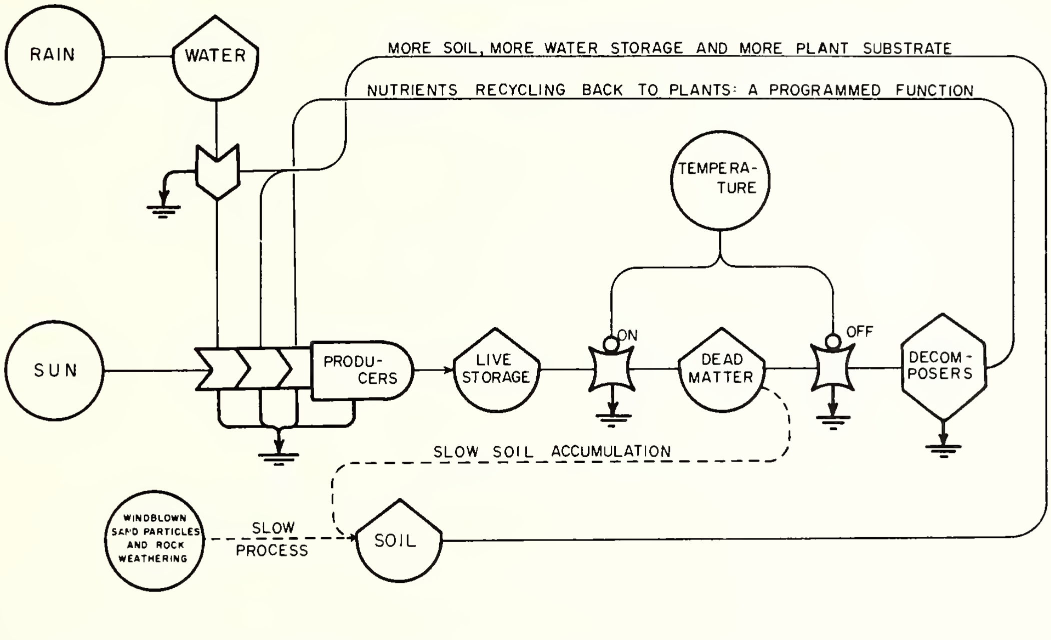

RAIN
WATER
MORE SOIL, MORE WATER STORAGE AND MORE PLANT SUBSTRATE
NUTRIENTS RECYCLING BACK TO PLANTS: A PROGRAMMED FUNCTION
TEMPERA-TURE
ON
OFF
SUN
PRODU-CERS
LIVE STORAGE
DEAD MATTER
DECOM-POSERS
SLOW SOIL ACCUMULATION
WINDBLOWN SAND PARTICLES AND ROCK WEATHERING
SLOW PROCESS
SOIL

Figure 37.-The timing of production and respiration in a granite-outcrop ecosystem. The sun is shown powering photosynthesis in the plant producers resulting in a live storage of organic matter. With the onset of winter and low temperatures, growth stops, the producers become dormant and the live storage becomes dead matter. This is shown being controlled by a switch(s) operated by temperature. In this diagram, the switch is ON (low temperature) and dead material accumulates. The temperature switch controlling decomposition is thus shown as being OFF. During this period, the dead material is slowly incorporated as soil which is shown to be also receiving windblown materials. In the spring, the temperatures rise opening the switch to the decomposers (bacteria, fungi, etc.) who begin working on the dead matter. During decomposition, the nutrients in the previous year's production are released to stimulate the current production. This is shown as a multiplier on production. The survival of this system depends upon the coordinated timing of production and decomposition with respect to season.

decomposition occurred. When spring arrived, however, the rate of decomposition increased rapidly towards a peak. An increase in plant photosynthesis soon followed. Figure 37 shows the close relationship between photosynthesis and decomposition in granite outcrops. The amount of mineral nutrients is low in the soil compartment. Essentially all mineral resources are tied up in the biomass. They are cycled rapidly between litter and plant biomass when it is to the best advantage to the system (due to changing environmental conditions) that the transfer take place. Similar timing mechanisms have been observed in several forest types. Usually an ecosystem will have some compartments that have short residence times during critical periods (leaves and litter) and other compartments with prolonged residence times (wood, epiphytic algae, and mosses). Each compartment has a function in the retention and release of nutrients and thus a role in controlling productivity. Examples will be discussed in the following sections.

Water Flow

The properties of Water: Water is one of three substances that occurs naturally in the liquid state (mercury and oil are the other two). Due to its molecular configuration (i.e., the arrangement of hydrogen and oxygen atoms) the water molecule is polar (i.e., partially charged) and has unique characteristics (Table 1). These characteristics have profound effects upon the environmental conditions under which organisms live and upon all life processes which occur in aqueous solutions. Many important ecological situations are the results of the properties of water, such as: the fairly constant temperatures observed in aquatic environments (heat storage capacity of water); the insulating effect of floating ice over warmer waters (highest density at 4° C); the transport of minerals in aqueous solutions (solvent capacity resulting from polarity); the cooling effect of transpiration in terrestrial plants (high heat of fusion); and insects' ability to walk on water (surface tension).

Table 1. some properties of water

Chemical formula	H_2O
Molecular weight	18.016
Boiling point	100° C or 212° F
Freezing point	0° C or 32° F
Maximum density	1.0000 grams/milliliter
Temperature at maximum density	3.98° C or 39.16° F

Movement of water through the biosphere: The hydrologic cycle (or water balance) describes the movement of water through the biosphere. Its main compartments include the atmosphere, streams, lakes, underground aquifers, oceans, ice, and biological structures. The main pathways of water flow among these compartments are precipitation, evaporation, and runoff. Of the total precipitation over land surface, about 1/3 is evaporated and 2/3 flows back to the ocean through runoff. The amount of water that percolates into underground water reservoirs (aquifers) is small compared to evaporation and runoff. Aquifer management and water management, in general, are critical, particularly in Florida, where most human communities depend on the aquifer compartment for their water supplies. The major storages and flows of water in a large land mass is suggested in figure 38.

The movement of water through forest ecosystems: Rainfall striking a forest canopy has several possible routes, the magnitude of water flow through each being a function of canopy structure. Water may be intercepted by the canopy, it may flow through the canopy into the soil (throughfall), or flow down over the stem surface of trees (stem flow). Water intercepted by the canopy may be evaporated, or it may eventually find its way to the substrate through stem flow or dripping from leaf tips. All possible flows are summarized as a budget for a mixed southern hardwood forest in figure 39.

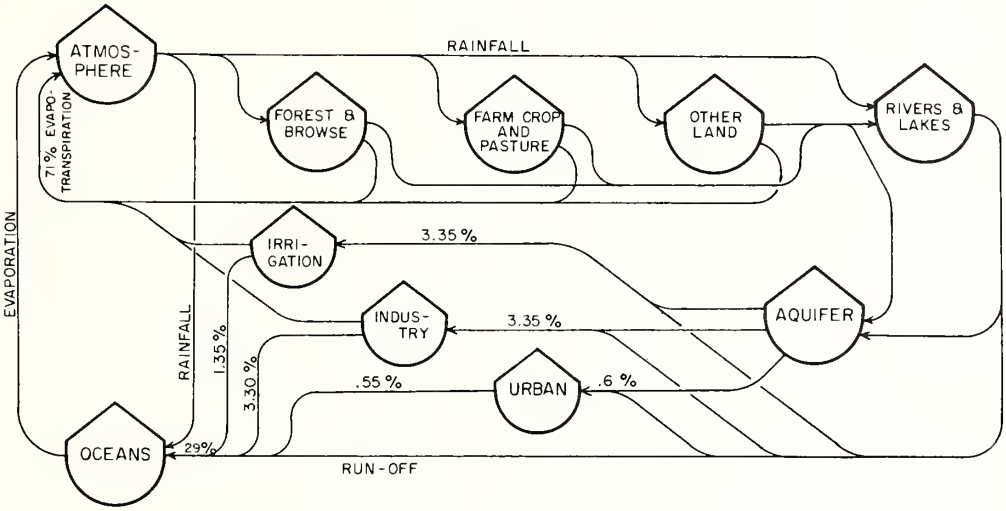


Figure 38.-The movement and storage of water. The major pathways along which water flows are rainfall, runoff and evaporation including transpiration. Each water storage compartment receives and loses water by one or more of the mechanisms. Most of man's activities (e.g., irrigation of cropland, industrial consumption, and urban uses), however, receive water directly from some terrestrial storage. Note that in terms of percentage that only a small fraction of the input is actually used; the remainder continues on to the ocean. This emphasizes that most of man's fresh water problems are basically related to the uneven distribution of water in space and time, i.e., deserts versus lakes and year-round rainfall versus wet seasons-dry seasons. (based on data from Revelle, 1963.)

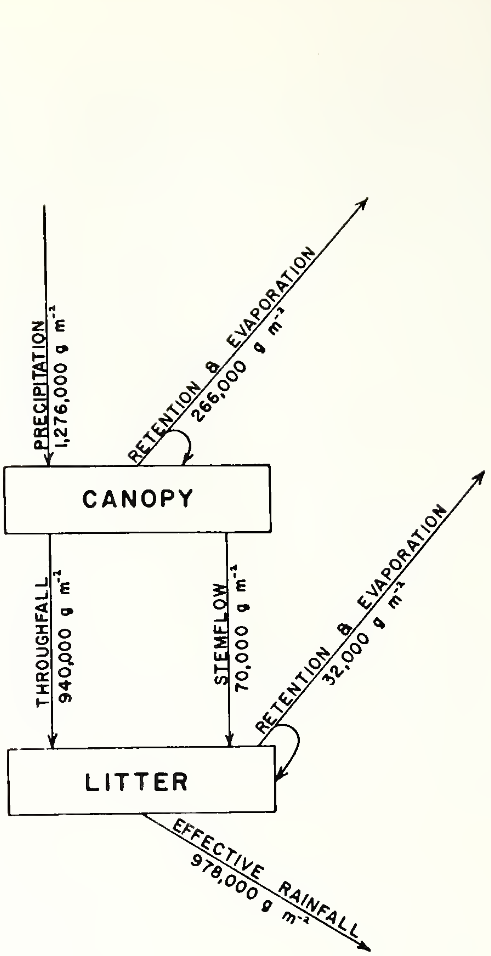


Figure 39.-A water budget for a southern hardwood forest. During the course of a year the rainfall equaled 1,276,000 grams per square meter (g m^{-2}) of which some 21% was retained in the canopy and lost back to the atmosphere through evaporation. Of the 79% which passed through the canopy 93% reached the ground as throughfall and 7% as stem flow. Of the precipitation reaching the forest floor, 3% was retained and lost through evaporation. Of the total precipitation, 77% or 978,000 g m $^{-2}$, was not directly evaporated and is considered the effective rainfall. The effective rainfall is lost through runoff, downward percolation into the soil, or through the process of evapotranspiration. A gallon of water weighs approximately 4,500 grams. (from Lugo, Snedaker and Gamble, 1972).

Once through the canopy, water may travel over one or several routes, the number and ype depending upon the topography, vegetational character, and soil characters. Water ithin the forest may (1) be absorbed by mosses, litter, and epiphytic vegetation (2) low out of the system through runoff, or (3) percolate through the soil into the water able beneath. Two other pathways, which depend upon the metabolic activity of the plant ommunity, are (4) reabsorption by plant roots, with resulting movement through the transiration stream, and (5) direct evaporation from the forest floor. These flows are illusrated in figure 40.

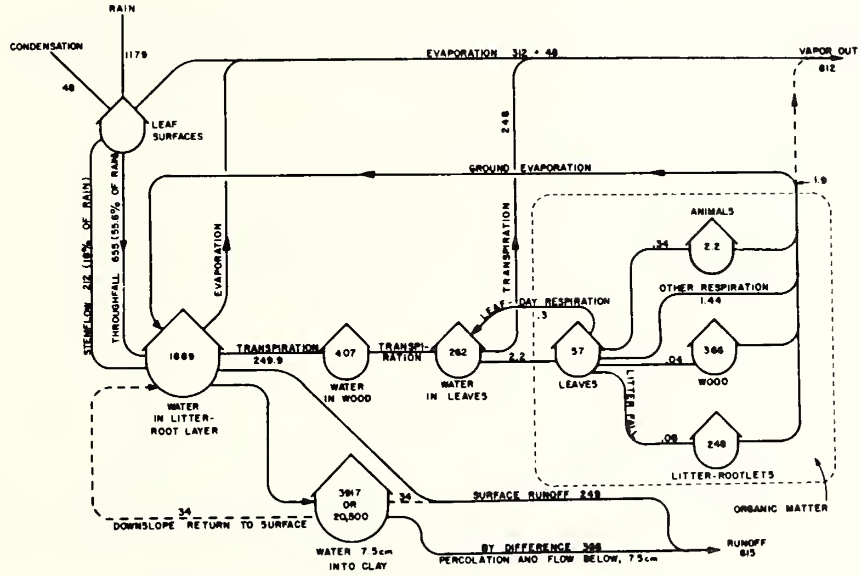


Figure 40.-The flow of water through an ecosystem. Water is essential to all life processes and its role in our overall life support system requires a thorough understanding of local, regional and biosphere budgets. Whereas, this figure describes the storages and flows in a rain forest, they are the same in any forest; only the values will be different. The dashed-line box separates the biological processes which use water from the physical processes which control its movement. Water input is through rainfall and condensation, and the major storage is the soil (divided here into litter/roots and clay to a depth of 7.5 cm). In the forest, water flows as throughfall, stem flow, percolation and surface runoff. Water is taken up by plants in the transpiration process; most is lost through evaporation and some is tied up in organic matter by photosynthesis. Respiration releases the water in organic matter. Note that the turnover, or the rate at which water moves through the forest is rapid (see figure 35). (from Odum, 1970).

Effects of, and ecosystem response to water flow: While water is necessary for vita biological processes (photosynthesis, respiration, cell turgidity, osmosis, translocation etc.) its passage through the system is potentially harmful. For example, heavy water flow through agricultural ecosystems causes erosion and losses of valuable mineral fertilizers. In addition, torrential rains cause structural damage to the community. Floodin if prolonged, depletes the air supply to roots -- a condition potentially lethal to these plant parts. How are ecosystems adapted to prevent such negative effects?

Figure 41 is a diagram of the nutrient-water flow through ecosystems. Rainwater contains dissolved nutrients which are incorporated from dust particles and other sources in the atmosphere. On an annual basis such input is significant when ecosystem growth requirements of these nutrients is considered (Table 2). In addition, as the water flows over the surface of the canopy leaves, more nutrients are dissolved into it through leaching from leaf surfaces. This may be an added stress on the nutrient budget of the system if these nutrients are lost from the system. However, as the water flows out of a climax forest, the amount of minerals found dissolved in it is negligible. Similarly, water reaching the water table contains only small amounts of leached minerals. The forest ecosystem acts as a filtering device for mineral-rich water, retaining the minerals while allowing 2/3 of the water to run off and the other 1/3 to be evapo-transpired.

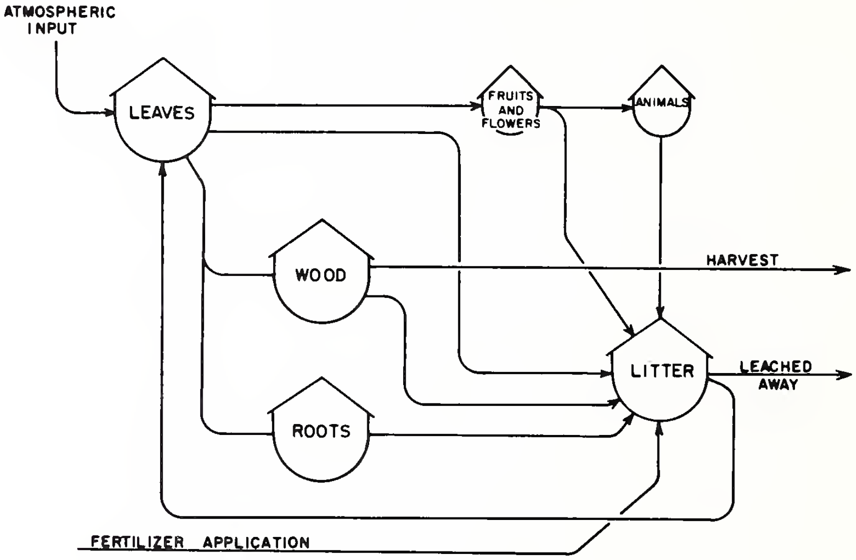


Figure 41.-Nutrients and water flow in an ecosystem. An ecosystem contains a finite amount of nutrients and circulates them among the system's storages. Gains to the system occur naturally through atmospheric input as dry fallout or in rainfall. Dry fallout (dust) is moved through the system also by water. Losses of nutrients occur in the litter compartment during the process of decomposition which releases the nutrients in a form available for re-uptake by plants. When man harvests a sizeable portion of the biomass containing these nutrients, fertilizer has to be added to make up the difference.

Table 2. - Magnitudes of nutrients in rainfall. (In part, from Ovington, 1968).

Nutrient	Kg/ha in rainwater
(to convert kilos per hectare to pounds per acre, multiply by 0.89)	
Nitrogen as:	
Nitrate	5.3
Ammonia	2.1
Potassium	23-28
Calcium	24-25
Magnesium	9-11

As water containing dissolved minerals flows over stems, it passes over rich growths f epiphytic algae, mosses, and higher plants (epiphytes are plants which grow on the urfaces of other plants). These species have high water retention capacities and effec- ively retain the mineral-rich drops of rainwater. The nutrients are re-incorporated into hese compartments which have a characteristically long residence time; that is, the utrients are subsequently released slowly over time, into the general mineral circulation f the ecosystem. However, some epiphytes are also capable of short-term storage, sometimes ransferring the nutrients directly to the parent plant. Shade leaves (characterized by arger leaf areas and slower metabolic rates), are often covered with epiphytic growth nd serve a similar storage function. The water that does not come in contact with trunk nd leaf surfaces must pass through the forest floor, where intricate root mats with their illions of absorptive small roots reabsorb minerals (figure 34) and return them to plant torage via photosynthesis. These biological structures are responsible for the reintegra- ion of leached minerals into the general circulation and also for the closing of the ineral cycles.

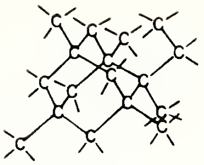
arbon Flow

The properties of carbon: Carbon is not plentiful in the earth's crust (less than .1%) but it is the second most abundant element in living matter (about 17%). (Oxygen s the most abundent). Carbon belongs to a group of elements that have only four electrons n an outer electron shell which has room for eight. Instead of losing or gaining four lectrons to arrive at a stable energy level, these elements share four electrons with ther elements. Carbon (silicon acts similarly) atoms share electrons with each other to orm the long chains which are the skeleton of all organic compounds (figure 42).

Movement of carbon through the biosphere: The carbon cycle is shown in figure 43. he main compartments are the oceans, fossil fuel reservoirs, living organic matter, and he atmosphere. As carbon flows through these compartments it is transformed into many ompounds, each with important effects on the environmental conditions of the earth. onsider the following examples:

(1) In the atmosphere, carbon is found in the form of carbon dioxide (CO_2). It constitutes 0.03% of the gaseious composition of air. Carbon dioxide absorbs solar radiation heavily in the infrared portion of the solar energy spectrum (figure 44) The absorption of infrared radiation by atmospheric carbon dioxide warms the earth and the result is known as the greenhouse effect.

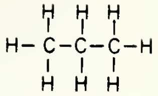
(2) CO_2 in the biosphere: carbon dioxide flows from the atmosphere into living components by way of plant photosynthesis. There, it is then incorporated in organic matter such as carbohydrates, proteins, and fats. When organized in these molecules the energy content of the compound increases and it becomes a source of energy which can be tapped through respiration. Respiration releases carbon to the atmosphere in the form of CO_2.



(a) Diamond, hardest substance known, pure carbon.

$O=C=O$

(b) Carbon Dioxide

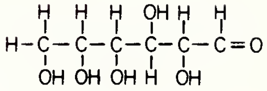


$$\begin{array}{ccccccc} & & H & & H & & H & \\ & & | & & | & & | & \\ H & - & C & - & C & - & C & - & H \\ & & | & & | & & | & \\ & & H & & H & & H & \end{array}$$

(c) Propane

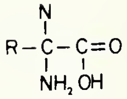
$H-C\equiv C-H$

(d) Acetylene



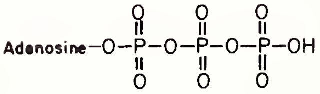
$$\begin{array}{ccccccccccccc} & & H & & H & & H & & OH & & H & & H & & \\ & & | & & | & & | & & | & & | & & | & & \\ H & - & C & - & C & - & C & - & C & - & C & - & C & = & O \\ & & | & & | & & | & & | & & | & & & & \\ & & OH & & OH & & OH & & H & & OH & & & & \end{array}$$

(e) Sugar (Glucose)



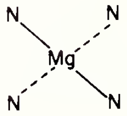
$$\begin{array}{ccccccc} & & N & & & & \\ & & | & & & & \\ R & - & C & - & C & = & O \\ & & | & & | & & \\ & & NH_2 & & OH & & \end{array}$$

(f) Amino Acid



$$\begin{array}{ccccccccccccc} & & & & O & & & & O & & & & O & & \\ & & & & \| & & & & \| & & & & \| & & \\ \text{Adenosine} & - & O & - & P & - & O & - & P & - & O & - & P & - & OH \\ & & & & \| & & & & \| & & & & \| & & \\ & & & & O & & & & O & & & & O & & \end{array}$$

(g) Adenosine Triphosphate



(h) Chlorophyll

Figure 42.-Examples of organic carbon compounds. All organic compounds are built around carbon, hydrogen, and is most instances, oxygen. Diamonds (a), however, are pure carbon. Of particular interest is the chlorophyll molecule (h) which is very large in size; only the central, innermost portion is shown here. The only difference between the chlorophyll of plants and the hemaglobin (blood) in man, is that iron is substituted for the Mg (magnesium) atom.

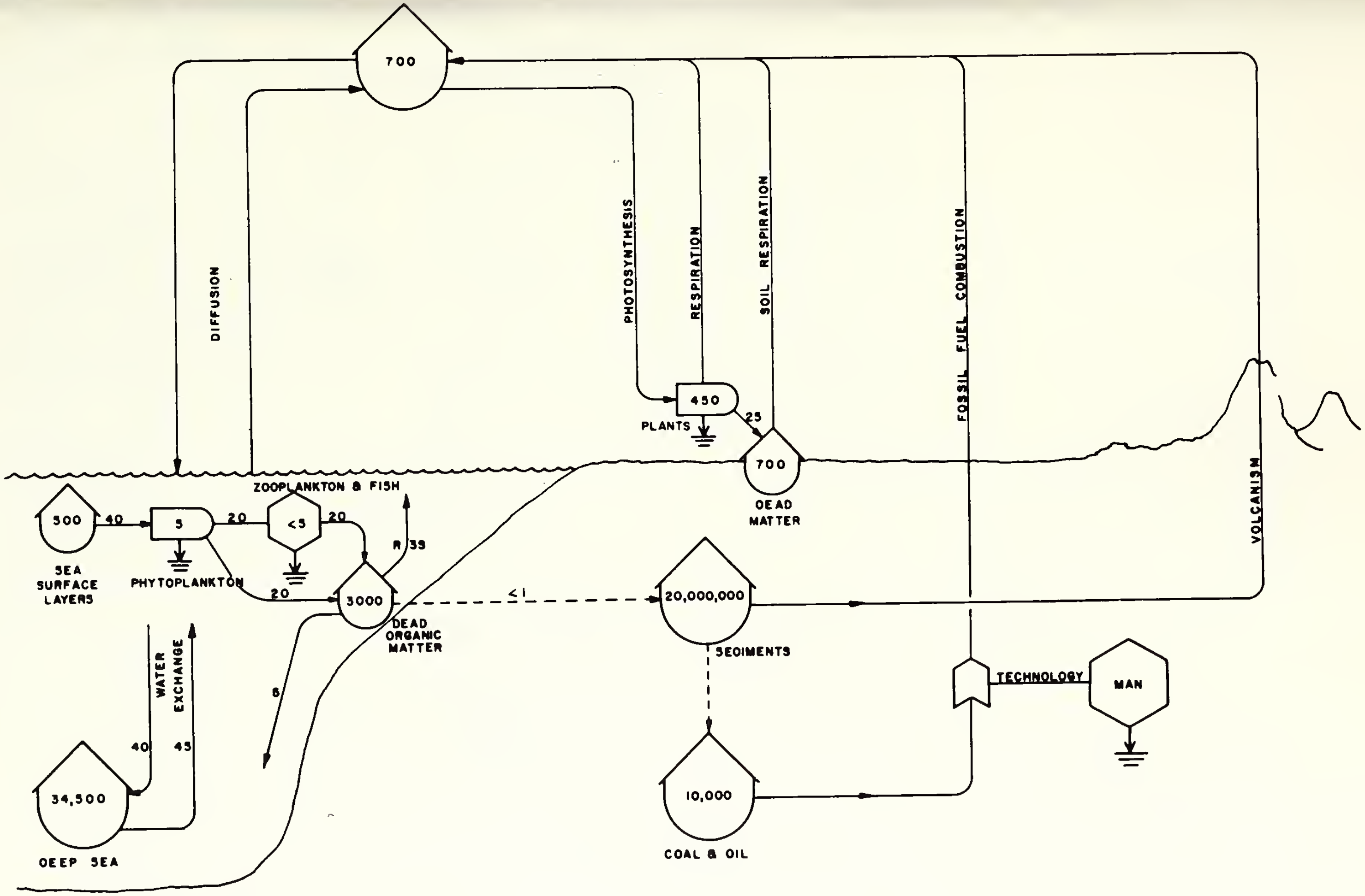


Figure 43.-Movement of carbon through the biosphere. Carbon continually circulates through the biosphere (e.g., carbon monoxide, carbon dioxide, and carbonate) moving into and out of diverse kinds of storages (e.g., plants and animals, ocenas, sediments and the fossil fuels, coal and oil). Each, as is seen in this diagram, is important to the overall functioning of the biosphere and the well-being of man. The numbers indicate relative magnitudes. (from Bolin, 1970.)

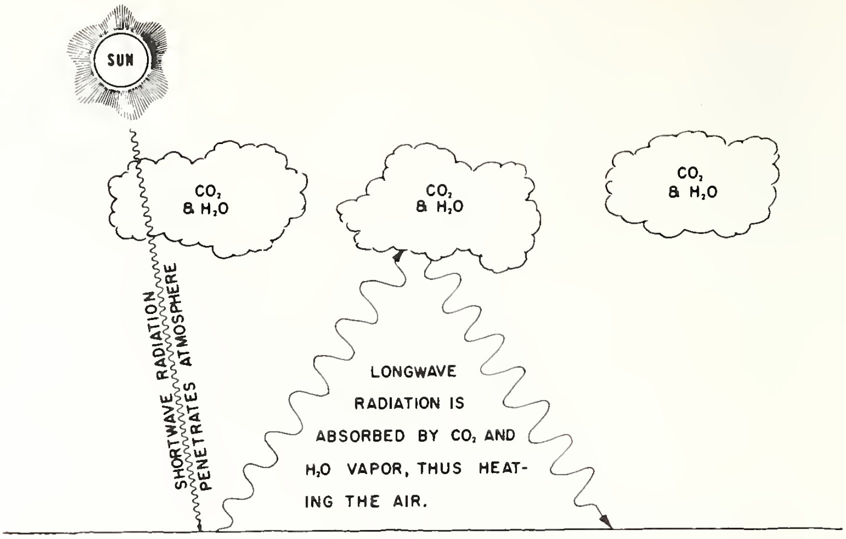

SUN
CO2 & H2O
CO2 & H2O
CO2 & H2O
SHORTWAVE RADIATION PENETRATES ATMOSPHERE
LONGWAVE RADIATION IS ABSORBED BY CO2 AND H2O VAPOR, THUS HEATING THE AIR.

Figure 44.-The greenhouse effect. Solar short wave radiation easily penetrates the earth's atmosphere. When re-radiated as long-wave radiation, however, the carbon dioxide and water vapor effectively absorb the energy. Thus, heat is trapped in the atmosphere warming the earth.

(3) CO_2 and water: Carbon dioxide reacts quickly with water, forming carbonic acid. This explains the slightly acid nature of rainwater or water in contact with decomposing matter. Carbonic acid in water can influence biogeochemical processes greatly by dissolving limestone in areas (like Florida) where limestone rocks ($CaCO_3$) are the dominant bedrock. Dissolution of the calcium carbonate in limestone produces the sink holes common to the topography of Florida. In addition, carbonic acid disassociates into bicarbonate ions and carbonate ions and these ions are then available as carbon sources for aquatic plant photosynthesis. They change the pH of natural waters and are involved in the buffering systems of these waters. The pH is a measure of acidity and buffering is a measure of the pH stability of a body of water. Waters rich in carbonates are highly buffered and their pH fluctuates little; those without an abundance of carbonates and other salts, have a low buffering capacity and their pH fluctuates widely. Figures 45 and 46 illustrate some of the dynamics of CO_2 in waters.

(4) Carbon and the sea: The sea is the largest reservoir of carbon. In the sea, most of the carbon is in the form of calcium carbonate ($CaCO_3$). The reservoir of calcium carbonate in the sea buffers its pH (figure 47) and serves to control the amount of CO_2 in the atmosphere through the diffusion of CO_2 into the air. In addition, $CaCO_3$ is the building block of skeletons of many sea creatures (algae and corals are examples). These organisms depend upon alkaline conditions to maintain these structures since $CaCO_3$ dissolves when the pH drops below 7. Therefore, $CaCO_3$ skeletons are common in tropical areas where temperature and pH conditions favor the precipitation of $CaCO_3$, but are absent in the polar regions where pH and temperatures are lower - conditions favoring the solubility instead of the precipitation of the $CaCO_3$. Silicon skeletons predominate in these waters. Notice that the conditions favoring the solubility or precipitation of a compound are utilized to the energetic advantage of the system. It would be energetically costly to maintain $CaCO_3$ skeletons in acid water. Such strategy would be similar to constructing and maintaining an igloo under tropical conditions! Discussed in Chapter V is the geological history of Florida which describes how calcium carbonate was deposited to form the limestone.

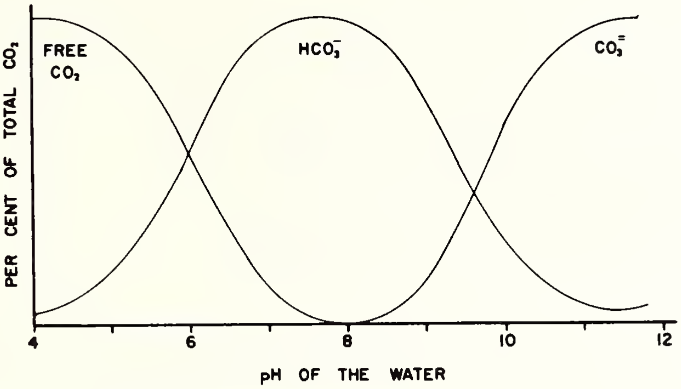


Figure 45.-Changes in the carbon equilibrium as related to changes in the pH of water. In acid waters, free carbon dioxide predominates while calcium carbonate ($CaCO_3$) is the dominant form in alkaline waters (high pH). (from Reid, 1961).

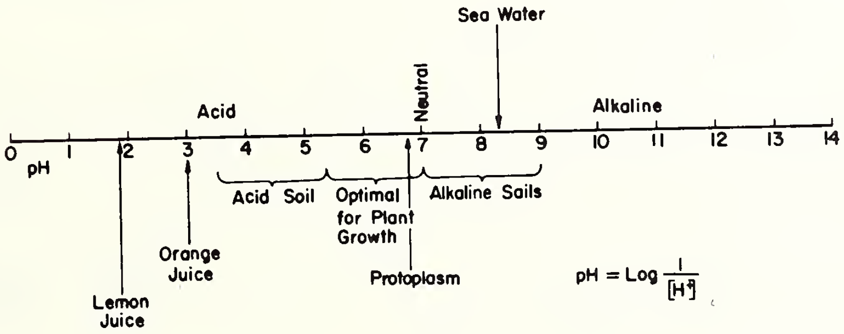


Figure 46.- pH as a measure of the hydrogen ion concentration. The scale of pH is shown using examples that are common to most of us. Note that pH is a measure of the hydrogen ion concentration in a liquid solution low pH's reflect acidity and high pH's alkalinity. (from Greulach and Adams, 1962.)

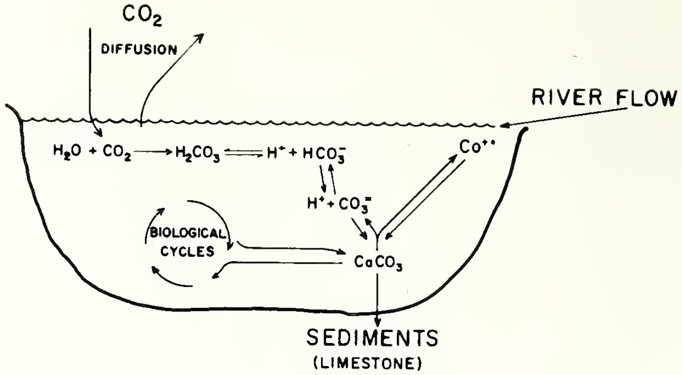


Figure 47.-The carbon equilibrium in a body of water. In a body of water, H_2O and CO_2 combine to form carbonic acid (H_2CO_3) which exists in an ionic equilibrium with $H^+ + HCO_3^-$. Calcium atoms (Ca^{++}) combine with the $CO_3^=$ to form calcium carbonate ($CaCO_3$) which may be used in short biological cycles or be deposited in the sediments for long lengths of time. These storages of calcium carbonate are known as limestone deposits. The diffusion of CO_2 between water bodies, primarily the oceans, exerts a controlling influence on other biosphere processes.

base. This occurred in warm tropical alkaline waters. Once formed and elevated, as it is now, it began being dissolved by more acid rain and surface waters to produce the contemporary topography and the water (fresh) bearing limestone aquifer. Thus, such a seemingly simple environmental factor as pH has a tremendously profound influence on the creation and maintenance of our immediate life support system.

Carbon dioxide and gaseous exchange: The low concentration of CO_2 in the atmosphere limits the rate of photosynthesis in nature. For example, figure 48 shows that at any specified light level in a forest ecosystem, the rate of photosynthesis may be increased by providing more carbon dioxide. This relationship describes CO_2 as being a limiting factor in that for a given set of circumstances, photosynthesis varies in proportion to the amount of available CO_2. It also provides insight into why agricultural/forestry efforts to increase productivity cannot expect quantum jumps in yield, when all factors are at their optimum, CO_2 will be limiting. However, under laboratory-controlled conditions where abundant CO_2 is made available, photosynthesis is limited by the amount of light to about 10 per cent of the incident energy. The two management problems, providing CO_2 above ambient levels and increasing photosynthesis efficiency, prevent the increase of yields much above the present levels.

Ecosystem exhibit various adaptations to maximize gas exchange. For instance, consider the size and/or number of leaves which may be stacked in volume. If they are too small or too few, then there is excess light in proportion to carbon dioxide and photosynthesis is not maximized. Conversely, if the leaves are too large or too numerous then there is insufficient light and probably too little CO_2, the latter due to poor flow among the leaves. The adaptations of the ecosystems maintain optimum photosynthesis by maintaining the proper leaf area index. Other mechanisms which serve to ensure adequate gas exchange include: (1) the large air cells in aquatic plants which facilitate gas transport from one end of the plant to the other (look for these in the water hyacinth), (2) the cypress knees in the swamp forest and the pneumatophores in mangrove swamps, and (3) a ragged leaf canopy which increases gas exchange through turbulence and eddy diffusion. The principles of gas exchange and some of the mechanisms are summarized in figure 49.

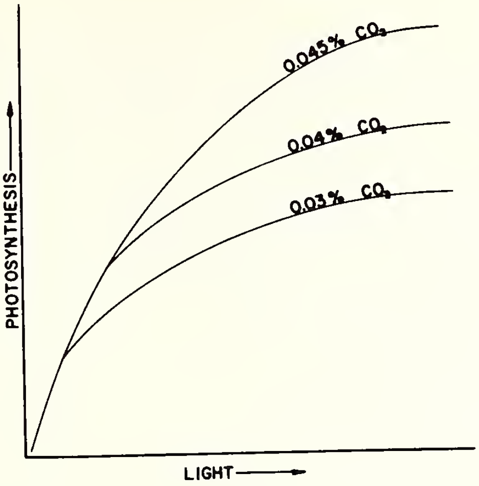


Figure 48.-Photosynthesis as a function of carbon dioxide and light. At any given level of light intensity above a certain minimum, photosynthesis varies in proportion to the amount of carbon dioxide (CO_2) present. Thus, under these conditions, CO_2 is the limiting factor on photosynthesis, i.e., it controls the rate of photosynthesis. In a closed canopy of a forest, the level of CO_2 decreases as photosynthesis occurs, thus reducing the rate. If, however, eddy diffusion or turbulence rapidly renews the CO_2 being used in photosynthesis, the maximum rate is maintained. (from Meyer, Anderson and Bohning, 1960)

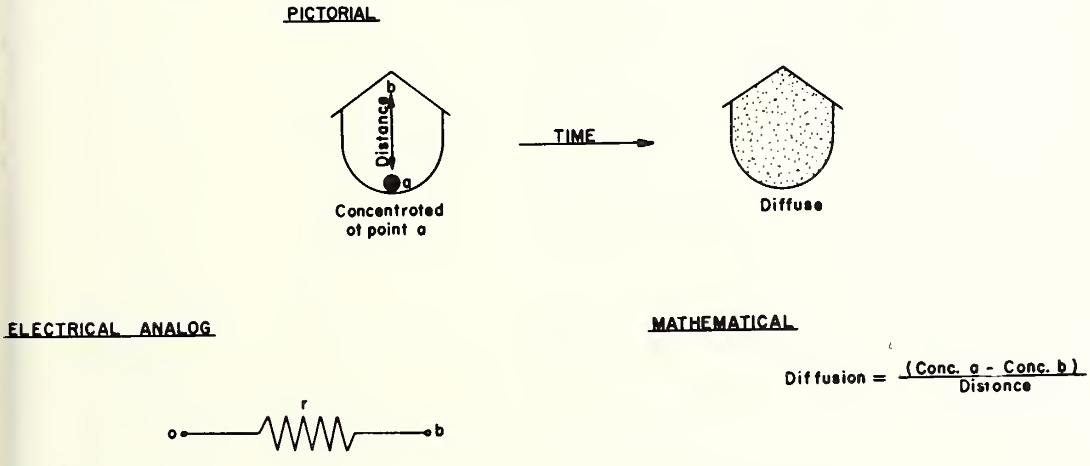


Figure 49a.-Fick's law of the diffusion of gases. Gas molecules will move from areas of high concentration to areas of lesser concentration until an equilibrium is attained, i.e., until the gas molecules are evenly distributed. The rate of diffusion, as shown in the mathematical expression, is proportional to the difference in concentrations between the two areas, and inversely proportional to the distance between the two areas. The electrical analog of Ohms Law expresses the same relationships:

$$\text{Current flow} = \frac{\text{voltage}}{\text{resistance}}$$

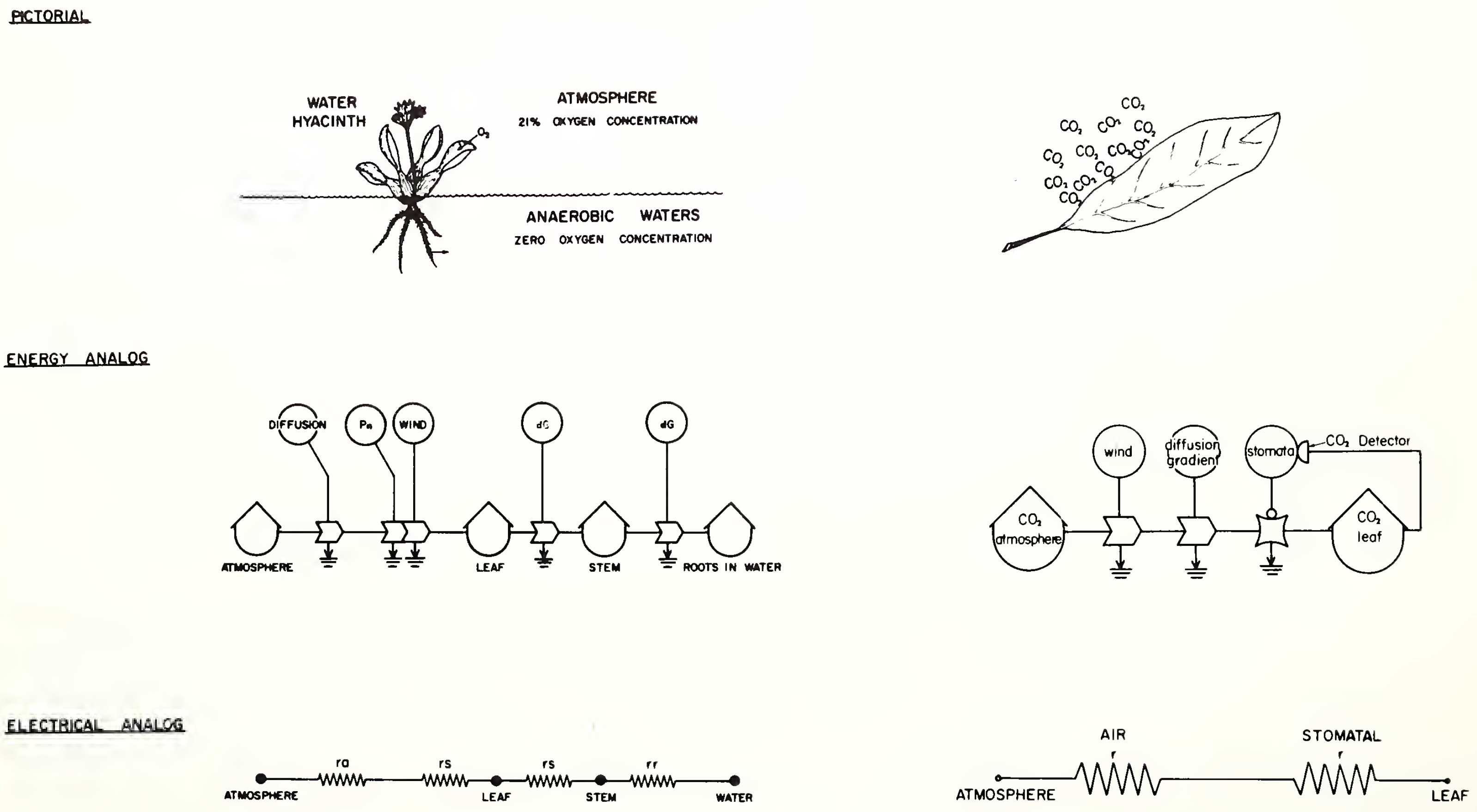


Figure 49b.-Two examples of gaseous diffusion in the biological world: Left - The diffusion of oxygen through the roots of an aquatic plant, the water hyacinth, and Right - The diffusion of carbon dioxide through the leaves of a plant. The forcing functions accelerating diffusion are shown in the energy diagram. The same subsystems are also expressed in their electrical analogs.

Energy Flow

The laws of energy flow and conversion: Throughout the text we have used such terms as energy, potential energy, free energy, work, and the laws of thermodynamics. While we already have an intuitive knowledge of their meaning, they will be formally defined in this section.

Energy is defined as the capacity to do work. It is measured in calories, and is defined as the application of a force over a distance. The laws of thermodynamics describe the behavior of energy transformations. The first law states that the total energy of the universe is constant. Energy, according to this law is not created or destroyed.

$$\Delta E = W + S \qquad \text{(FIRST LAW)}$$

change in energy = work + storage

The second law states that all energy conversions in the real world (such as energy exchange between trophic levels or those in the motor of a car) are less than 100% efficient.

$$\Delta H = \Delta F + T\Delta S \qquad \text{(SECOND LAW)}$$

$$\begin{array}{lcl} \text{change in} & = \text{change in} & = \text{change in entropy} \\ \text{enthalpy} & \text{free energy} & \end{array}$$

The second law thus precludes the existence of a perpetual motion machine since such a gadget requires 100% efficiency in order to operate. Examples of efficiences of energy conversion are given in Table 3.

Table 3. - Some magnitudes of efficiences for various machines and organisms.

Gross plant productivity (world wide)	2%
Herbivores in general	0.5-49%
Steam engine	10%
Automobile engine	25%
Well-designed electric motor	80%
Alternating-current transformer with no moving parts	98%

The second law also explains why energy in ecosystems does not recycle, like minerals, but instead flows one way with all the energy eventually dissipating into heat. The term ΔF represents the free energy of a system which is the energy available to do work. $T\Delta S$ is the entropy (the amount of disorder) of a system. Entropy must be positive if an energy conversion is going to be irreversible, or in accordance to the second law (less than 100% efficient). ΔH is defined as enthalpy (the opposite of entropy, or order), or energy content of matter. When one talks about the caloric value of food (4.5 Kcal/gm) one is talking about the enthalpy of the food. Given a source of potential energy (energy which can do work upon release) some of the energy will be used as free energy (actually doing useful work) and some will be lost as entropy, an energy tax which makes the process irreversible.

The rate of entropy generation or the rate at which disordering occurs as it increases, decreases the amount of free energy. This rate is related to the speed of energy conversion. The faster the rate of work generation (defined as power) the lower the efficiency. Conversely, the slower the power generation, the higher the efficiency. Figure 50 shows the relationship between power and efficiency. Notice that maximum power is generated a 50% efficiency. Figure 51 depicts the relationships of power output of plant photosynth and efficiency and shows that the high photosynthesis yields are only possible at low efficiencies. The highly publicized algae cultures with high efficiencies have low yields per unit area.

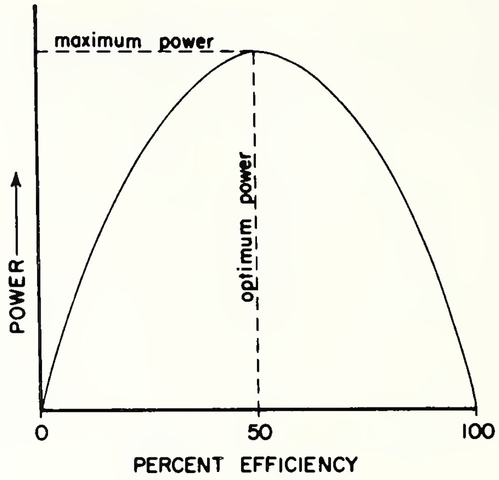


Figure 50.-The relationship between efficiency and power output. Power is the rate at which work is performed and power output is lowest both at very high efficiencies and at very low efficiencies. Maximum power output is obtained at an efficiency of 50%. An auto, for instance, is more efficient at a speed of say 45 mph than it is at either 5 mph or 90 mph. (from Odum and Pinkerton, 1955).

Another ecological phenomena explained by the energetic laws is the decrease in the number and biomass per unit area of organisms as energy progresses through the food chai Since food chains are energy conversion chains, it follows by the second law of thermodynamics that at each energy conversion, entropy will be generated and the free energy decreased. Therefore, organisms at the end of the food chain must increase their territories or somehow concentrate food from many food chains in order to obtain enough energ for their metabolic demands. Man applies his ecological intuition when he supports larg populations by harvesting and utilizing plants, which are closer than herbivores to the primary energy source (the sun). By doing this, more free energy may be obtained at a lower cost.

Some theoretical considerations: It follows from all the previous sections that ecosystems contain energy receptors, energy converters and units of storage. These compartments are coupled by energy flow and feedback mechanisms. Therefore, the laws of energetics have control over the development and maintenance of ecosystems. Some of the questions that come to mind about ecosystem function are: What is the maximum rate of production in a system? Are ecosystems close to this maximum value? How do different developmental stages of succession compare in their photosynthetic outputs? Has natural selection favored systems with maximum power output or those with maximum efficiency?

The energetic efficiency of ecosystems is determined from primary productivity data. Some ecosystems, however, have low primary productivity but may contain nevertheless a large animal biomass. The fauna (animals) of these ecosystems are supported by organic imports (allochthonous material) from other ecosystems. Rivers, lakes and estuaries are examples of ecosystems which obtain more energy from allochthonous detritus than from primary production, mostly through the decomposition process described in figures 16 and 17. In these systems, zooplankton (very small aquatic animals) feed on bacteria, which may be a substitute for algae as the base of the food chain. These bacteria are also important in coupling the anaerobic processes (those that do not require oxygen) occurring in the sediments with the aerobic processes (those that require oxygen) of the water (figure 52). In our discussion of ecosystem energetics, those ecosystems in which primary production predominates will be emphasized as they are characteristic of the terrestrial ecosystems and the aerobic springs in the Ocala National Forest.

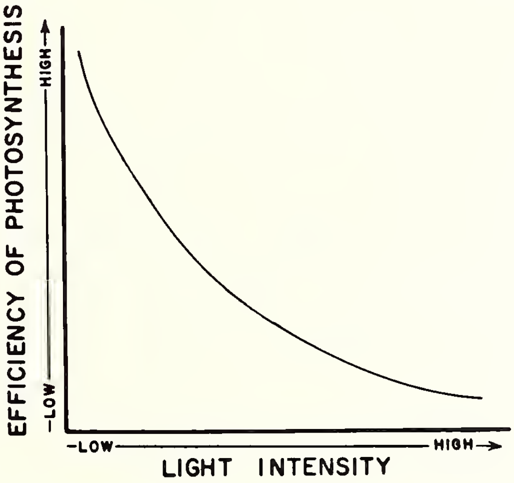


Figure 51.-Light intensity and the efficiency of photosynthesis. The efficiency of photosynthesis, or in other words, the highest rate of conversion of solar energy to chemical energy, is greatest at low light levels. The absolute yield (net production), however, is greatest when the light levels are high and the efficiency is low. Agriculture and forest management practices are geared maximizing yield rather than efficiency. (from Lemon, 1963).

Table 4 contains the magnitudes of primary production of several types of ecosystems. A distinction is made between gross and net production. Gross production includes day respiration while net production does not (gross production equals net production plus respiration). Determinations of productivity are made by measuring the net oxygen and carbon dioxide exchanges occurring between plants and the atmosphere. You will recall from figure 9 that during photosynthesis, oxygen is produced and CO_2 absorbed in proportion to the production of organic matter. This procedure of measurement has many sources of error of which ecologists are aware. For example:

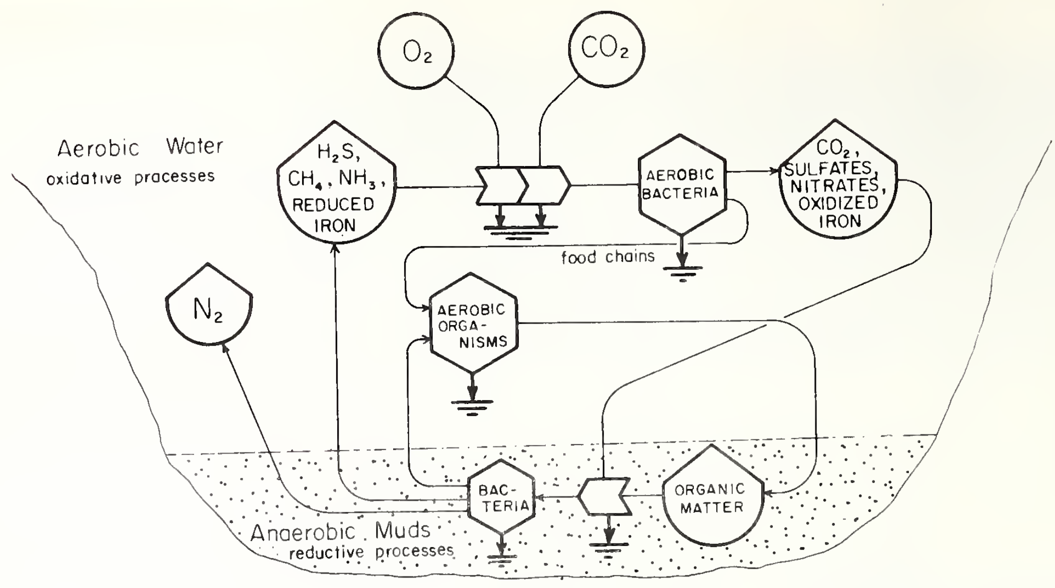


Figure 52.-The coupling of reducing and oxidizing systems. This figure illustrates the general interactions which occur between two chemical environments: aerobic (oxidizing) and the anaerobic (reducing) systems. The aerobic systems represent those environments where oxygen is present in relative abundance. The presence of oxygen and its addition to another compound or element in a chemical reaction is known as oxidation. Thus, the addition of oxygen which involves a loss of electrons by removing hydrogen in a reaction is the predominant process in the aerobic world to which man and the plants and animals at the base of his food web are adapted. In the anaerobic world oxygen is absent and obviously organisms must be adapted to live without oxygen. Under these conditions chemical oxidation is carried on without oxygen with the loss of electrons depending on chemical compounds other than oxygen. The dominant process in anaerobic environments is reduction which is the opposite of oxidation. During reduction, electrons are gained, oxygen is given off and hydrogen is added to the compounds or elements in the reaction. The alert reader will realize that photosynthesis is a reductive process which yields oxygen and incorporates hydrogen in carbohydrates, while respiration is an oxidative process which requires oxygen and yields hydrogen. When one substance is oxidized, another is always reduced. Likewise reduction is always oxidized, although both processes do not necessarily occur simultaneously. For instance, in anaerobic environments, chemical compounds tend to become reduced because the environment is conducive to reduction. In aerobic environments, the conditions are conducive to oxidation. Thus, organic matter will decompose (oxidizing) easier in an aerobic environment as compared to an anaerobic environment where it will be preserved. Anaerobic environments are characteristic of lake bottoms, sea floors, and swamp soils to which aerobic systems are coupled by the actions of biological organisms and the physical diffusion of reduced and oxidized substances through the envrionment. Notice that in the figure bacteria are shown as the main anaerobic organisms which feed on the reduced products of the aerobic world, namely the organic matter in the sediments to derive energy for metabolism. The oxidized materials are reduced in the process and are known as oxidation agents. Thus, methane (CH_4), hydrogen sulfide (H_2S), ammonia (NH_3), etc., are the reduced products of the anaerobic world and are subsequently utilized by aerobic bacteria which the oxidize them to complete a cycle. The oxidation is done in the presence of oxygen and CO_2 from the atmosphere, or water medium. The figure also shows other aerobic organisms consuming both the aerobic and anaerobic bacterial which contribute organic matter to the sediment through death. The reader should note that in this coupled system of oxidation-reduction, major elements such as sulfur (S), nitrogen (N), iron (Fe), carbon (C), hydrogen (H), and oxygen (O), are involved, the perpetually cycling of which are the results of numerous micro-organisms. (based on Sorokin, 1965).

(1) It assumes that daytime respiration is equal to nighttime respiration. This assumption is made when calculating gross production, simply because no method is available for measuring respiration while photosynthesis is also occurring. Data from laboratory experiments, where sophisticated conditions permit intensive manipulation of plants, suggests that photorespiration (respiration induced by light) is probably up to 100% higher than dark respiration. This invalidates the assumption of equal day and night respiration when working with systems with high photorespiration rates.

(2) "Productivity" is not a one-time energy conversion process, but is composed of many energy transfers which occur along the biochemical pathways (figure 53). Losses to entropy occur at each step as work is performed. These losses cannot be detected by gas exchange techniques or any other available method. This lowers our estimate of production.

(3) Energy-rich molecules (ATP) used to perform all cellular work are produced in the early steps of photosynthesis (figure 9) without the release of oxygen or consumption of CO_2.

(4) Oxygen and CO_2 may be recycled within the plant without net exchange with the atmosphere. This is particularly true in aquatic plants which have extensive internal air spaces for this purpose.

Table 4. - Gross production of selected ecosystems. (from Odum, 1971).

Sub-tropical oceanic blue water	2.9	Kcal/m^2 day
Sugar cane	74	Kcal/m^2 day
Water hyacinths	20-40	Kcal/m^2 day
Coral reefs	39-151	Kcal/m^2 day
Tropical rain forest	131	Kcal/m^2 day
Silver Springs, Florida	70	Kcal/m^2 day

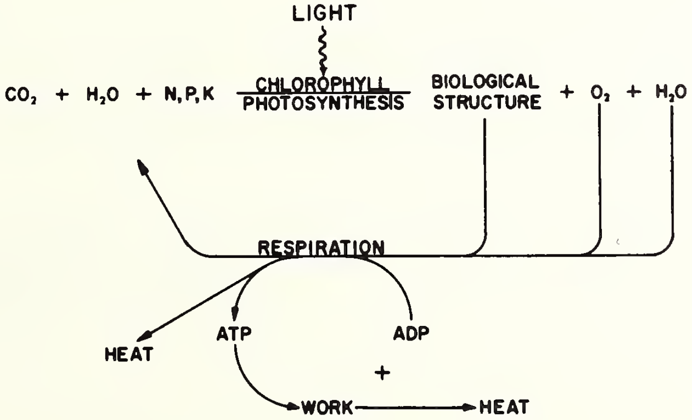


Figure 53.-The limitations on photosynthetic production. Photosynthetic production yield organic matter in the form of biological structure which ultimately is respired for work with a loss of heat. The formation of organic matter is potentially limited by light and/or the materials CO_2, H_2O, or such required elements as nitrogen (N), phosphorus (P) or potassium (K). All ecosystems have various functional mechanisms adapted to maximize energy flow under normally occurring regimes in the amounts of the factors.

All these errors underestimate productivity, thus probably making current estimates of ecosystem productivity low. However, new techniques are being developed that will correct for some of these sources of error. With these limitations in mind, we may proceed to discuss some of the exciting things we are learning about ecosystem function which relate to those questions asked at the beginning of this section.

From figure 53 we may theorize, similar to our discussion on CO_2, that the process of production is limited by three combinations of factors:

(1) limited nutrients but abundant light energy.
(2) limited light but abundant nutrients.
(3) limited light and nutrients.

Examples of the three situations are encountered in the Ocala National Forest. The springs of the National Forest are examples of systems with abundant nutrient supplies but limited light conditions. Nutrients are supplied from underground reservoirs and enter the system in the constant year-round water flow. However, as the spring flows through forests, leaf canopies intercept much of the incident light, reducing the amount available to the spring community. In addition, as the depth of the water increases, light is absorbed by the water itself reducing the amount of light available to bottom plants. The upper leaf layers of the climax terrestrial communities of the forest are examples of systems limited by nutrient but not by light. The sandy soils of Florida are nutrient-poor and this sets a limit define by the nutrient budget of forest ecosystems. Light however, is plentiful. Communities growing in shade and in sandy soils are examples of systems limited by both light and nutrients. The forest floor of a mesic hammock is an example of such system.

In several instances in this Chapter, we have made references to the fact that the availability of sunlight and carbon dioxide control the rate of photosynthesis and therefore productivity (see figure 48). If we consider that the amount of nutrients remains relativel constant in an ecosystem (only the distribution within the system changes), then productivit must be primarily a function of sunlight and carbon dioxide. These relationships are shown in figure 54 using productivity data obtained for an ecosystem in North Carolina. Data on the productivity of the terrestrial ecosystem of the Ocala National Forest are not available However, when comparing data from similar types of ecosystems in other regions with data on the springs, rates of gross production are similar in magnitude. Date from many climax ecosystems is starting to show an interesting pattern: regardless of the envrionmental stresses operating in the locality, climax systems have roughly the same magnitude of primary productivity. This magnitude is presumed to be the maximum theoretically attainable value for the site.

If climax systems approach the theoretical maximum production for a site, why do they exhibit different biomass contents (Table 5). Shouldn't all systems have similar net productions? The answers to these questions are not fully known but we may gain some insight by analyzing the rates of respiration (maintenance) in different climax ecosystems.

Table 5. - Biomass of selected ecosystems. (from Rodin and Basilevich, 1967).

oak forest	40,000 g/m^2
savannah	6,650 g/m^2
mangrove swamp	12,730 g/m^2
rain forest	50,000 g/m^2

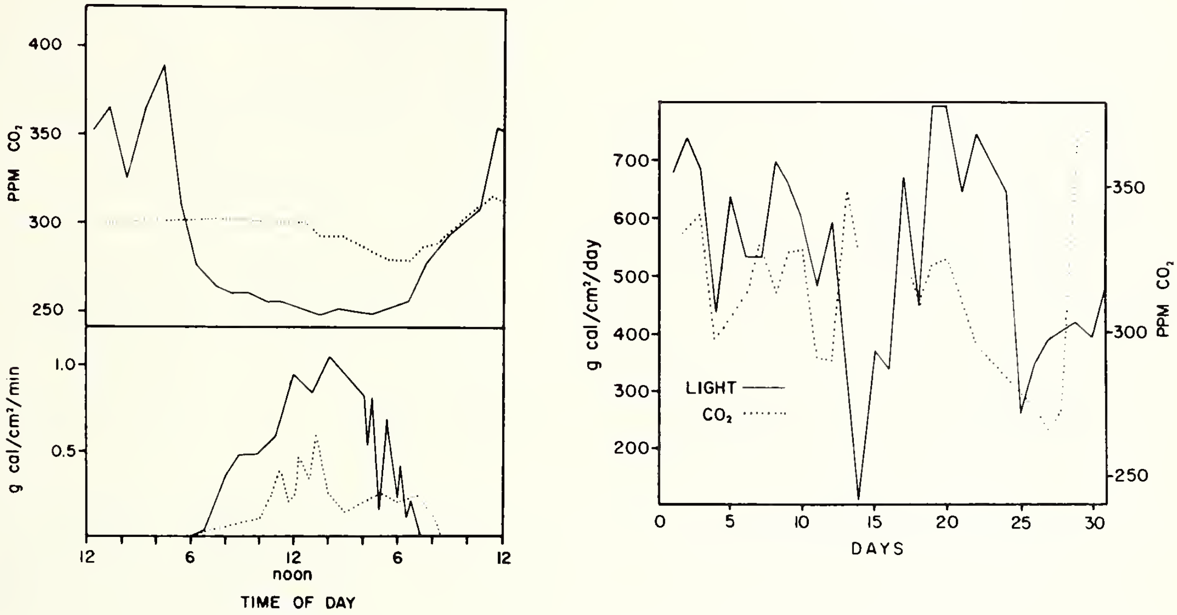


Figure 54.-Photosynthesis, atmospheric carbon dioxide concentration and solar radiation. (a) On a bright sunny day (dotted lines), photosynthesis proceeds at faster rates and for larger periods than on a cloudy day (solid lines) when the process is limited by the amount of incoming solar radiation. Photosynthesis is expressed in gram-calories of energy assimilated per square centimeter per minute in the bottom portion of the graph. In the upper portion, note that the amount of CO_2 in the atmosphere is related to the incoming solar radiation. During the daylight period, CO_2 decreases due to uptake in photosynthesis and during the night it increases due to its release during respiration. Because the photosynthetic rate is higher during a sunny day than during cloudy days, the two curves are highly contrasted. (b) In this graph, the mean daily CO_2 concentration in the atmosphere (dotted line) and the total daily incoming solar radiation (solid line) are plotted for comparison. After about 20 sunny days of high photosynthesis, the amount of CO_2 in the atmosphere decreases. In this study, cloudy days occurred after about 25 days which resulted in an excess of CO_2 release (respiration) over CO_2 uptake (photosynthesis). (from Lugo, 1969).

We have already discussed the variety of stresses imposed upon ecosystems in various localities. Each stress represents an energy drain on the storages of the system. Unles an external auxiliary energy source is available to "pay" for the stress, increases in respiration are necessary. "Stress drains" reduce the net production and therefore the rate of storage of biomass in the community.

If minerals are limiting to a system while light is abundant, the rate of production will be limited by how fast the minerals are regenerated for use in the photosynthetic process. The system responds to the stress with a low storage capacity (low biomass) and very high respiration rates. This speeds the movement of mineral nutrients and lowers th biomass, but maintains a very high rate of gross production. The planktonic systems of clear spring-fed waters in Florida and the longleaf pine-turkey oak communities are examp of this kind of system. Accelerated mineral cycling and high biomass is also possible if the nutrient pool allows a large biomass storage (swamp forest). When the minerals are abundant but light is not, ecosystems stratify their canopies (form many layers of leaves with the result that most of the light is intercepted by leaves before it reaches the ground (mesic hammock). Creating and maintaining such stratification will cost energy. Again, an increase in respiration is the only mechanisms available to obtain energy usefu for doing work in the system. The productivity of the lower stories of stratified commun ties is limited by both light and minerals. In these systems efficiency of light and nutrient utilization is crtical to productivity. Turnover rates of nutrients are low, and leaf areas and chlorophyll content per area are high. Under conditions of limited light and minerals, efficiency, rather than power output, is the factor critical to survival. Power output is favored only when a strong energy source is available.

Throughout succession, ecosystems organize their structures and functions toward the end result of maximum productivity. However, as the structure becomes more complex, the maintenance costs increase (as evidenced by increases in respiration and decreases in net production). The knowledge of the energetic development of ecosystems, with its many strategies to maximize productivity, is critical to their management by man, particularly in the areas of agriculture, forestry and range management, whose goals are the maximization of ecosystem net productivity.

THE PRINCIPLES OF ECOSYSTEM MANAGEMENT

ntroduction

Man has managed ecosystems for as long as history has been recorded and through sucessful management, he has been able to emerge as one of the dominant species on the planet. ther species have not been as fortunate, however. With the origin of agriculture a large umber of species became extinct, some say as a result of man's activities. Lately, the uccess of our modern land management techniques contrasts sharply with the deterioration f the environment and its capacity to support life.

There are two general types of ecosystem management. One is involved with increasing he net production of food and fiber (wood, cotton, hemp, etc.) and the other with the anaging of systems for one or more services to man. Examples of the first are agriculture nd forestry. The use of ecosystems for recreation (Alexander Springs), water storage Lake George) or transporation (Intra-Coastal waterways) are examples of the latter. hile each type of management requires a different strategy, both have as a common ecological oal, the coupling of man to nature.

anagement and Subsidy

The various functions carried on by ecosystems all require energy and the sum total f all energy allocations to these functions is the energy budget of the ecosystem. nce management involves the manipulation of the processes of ecosystems, it is in ality, the manipulation of the energy budgets of ecosystems. Through management, cerain energy expenditures are favored over others. For example, in forestry, man controls mpetition for light by thinning out non-producing trees and/or planting them at certain stances. By doing so he is increasing the net growth of the most desired trees in a rest. If such manipulation was not made, the trees themselves, through competition and penditure of photosynthetic energy, would have adjusted their growth patterns to the evailing and environmental conditions. However, because of increased respiration, net owth in the natural stand is lower. Through the work of man, the system increases its owth by decreasing its respiratory losses. Man subsidizes the system with his own energy serves. One strategy of management is, then, to replace the energy expenditures of the rest with energy from outside sources (the subsidy). This is similar to the government bsidy to agriculture. The consumer, however, pays the subsidy through income tax. In e "real" world, nothing is free (in terms of energy and perhaps even money!).

When man was less advanced, technologically, than he is today, he had small energy urces available, so his subsidies were small (mostly manual labor and primitive tools). elds were also small because the system still had to provide most of the energy necesry for its maintenance. As man discovered fossil fuels and developed an advanced techlogy, he could increase subsidies to the point of almost total protection of the ecostem. New species were designed and bred in controlled conditions (development), planted (eproduction and germination), grown in heavily fertilized soils (no limiting factors or cling needed), watered, protected from disease and weed competitors, etc. By providing ch subsidies, yields significantly increased, but so did the energetic and monetary st of maintaining such systems. Figure 55 shows the relationship between yield and the st of subsidy for agricultural systems and forestry. Several points are evident:

(1) Intensive management does not lead to more productivity than that which natural ecosystems are capable of producing. It does, however, convert gross production into net production (yield) by providing the maintenance energy from external sources.
(2) Regardless of management intensity, the maximum theoretical gross production cannot be exceeded.
(3) At high intensities of management, yields tend to equal subsidy.

(4) High intensity management has a high power output, but a low efficiency. Low intensity management is the opposite.

(5) Such management techniques can be justified only if a strong and reliable energy source is available to maintain the desired output level. Considering our current supplies of fossil fuels, one might question the availability of a strong energy supply, and the potential of modern agriculture to increase its output considerably. We might be cultivating less land today because we cannot afford more!

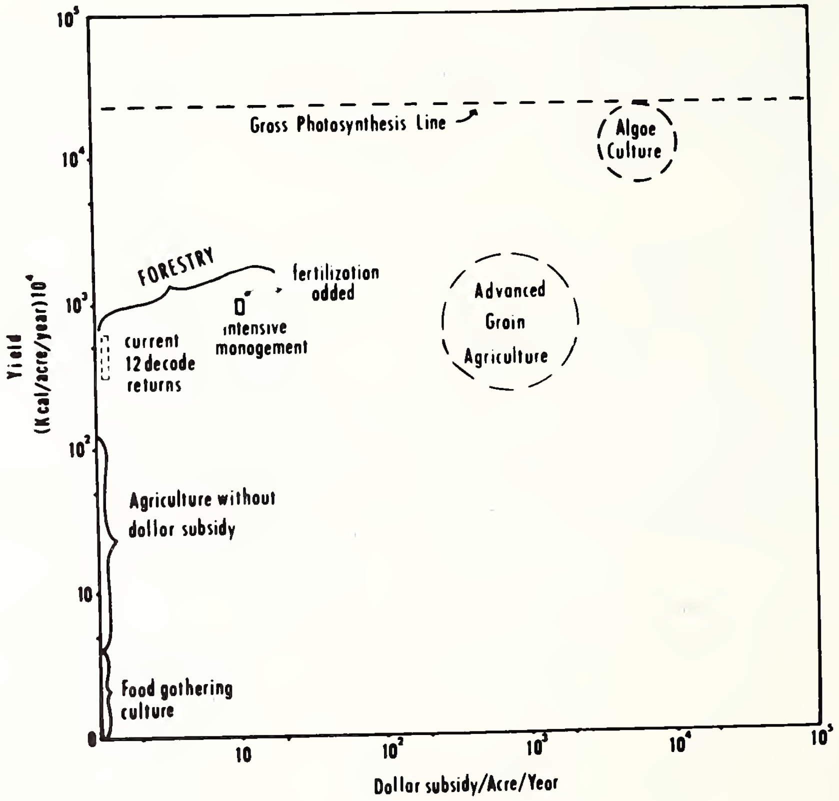


Figure 55.-Yields and dollar subsidies in forestry and agriculture. Agricultural production data was plotted from Odum (1967) and forest production data from figure 57. Board feet/acre/year were converted to kilocalories/acre/year using the following conversion factors: 1 cf = 6 bd-ft; 1 cf = 28,320 cc; wood density = 0.7 gm/cc; 1 gm = 4.5 kcal. Forest production relative to dollar subsidy is higher than for agricultural production. A continued increase in forest subsidies will reduce this production efficiency as illustrated by the extreme example of algal cultures. The gross photosynthetic line is the maximum possible output that any solar energy-converting industry (e.g., photosynthesis) can attain. (from Lugo, 1970).

Subsidy and Stress

The degree of subsidy required to keep a system operational is proportional to the complexity of the system and its adaptations to natural environmental stresses. Systems with only a few species are simple systems, subject to fluctuations and therefore expensive to maintain. A spaceship is an extreme case of a very simple system requiring total subsidy. Spaceship earth requires no subsidy to support life. Agriculture and forestry are in between, with agriculture close to the spaceship, and forestry close to spaceship earth.

Environmental stresses increase the need for a subsidy. The closer the system is to its natural range of adaptations, the smaller will be the subsidy required to maintain it. For example, citrus groves are adapted to warm conditions. The farther north they grow, the more expensive it is to maintain them. With enough energy, they could be maintained at the poles!

The Ecological Model

The problems of heavily subsidized systems are:

(1) They are expensive (energetically and economically).
(2) They are simple, and therefore subject to extreme fluctuation (caused by pest disease, etc.).
(3) They require constant care.
(4) They lack the structure to close their mineral cycles, thus loosing quantities of mineral nutrients which must be constantly replenished through fertilizers.
(5) They place large demands upon natural resources (mineral, water, electric power, etc.).

Their main asset is a high net production. Figure 56 shows that, over the last decade, total production has not increased significantly despite the increases in subsidies and multiplication of demand.

The ecological solution requires the coordinated action of all facets of society, including the consumer. It assumes that the thermodynamic limit of production will not be surpassed and that the effectiveness of subsidizing ecosystems has a limit set by the degree of stability desired. The maximum gross production has been achieved by natural ecosystems and natural ecosystems also have the complexity required for stability. The ecological approach to management seeks to conserve as many species as are needed to achieve high production and adequate stability. It recognizes that, while it is theoretically possible to convert the earth into a totally subsidized system, the danger of a single event completely eliminating the system precludes placing much faith in such strategy.

The first step in the development of an ecological management plan is the construction of ecological land use plans. These land use plans are based on the principle that different ecosystems are adapted to different environmental stresses. Therefore, in planning the use of land the adaptations of ecosystems are the principal considerations which will eventually lower the cost of subsidy. For example, flood plains are ideal places for recreation and agriculture, but not for housing or industry. Estuaries are ideal for the production of sea food, but this use is incompatible with the construction, housing developments or cities. Living units are best scattered in different concentrations according to the tolerance of the ecosystem. A pine flatwood area would tolerate larger intrusion than a sand dune, for example.

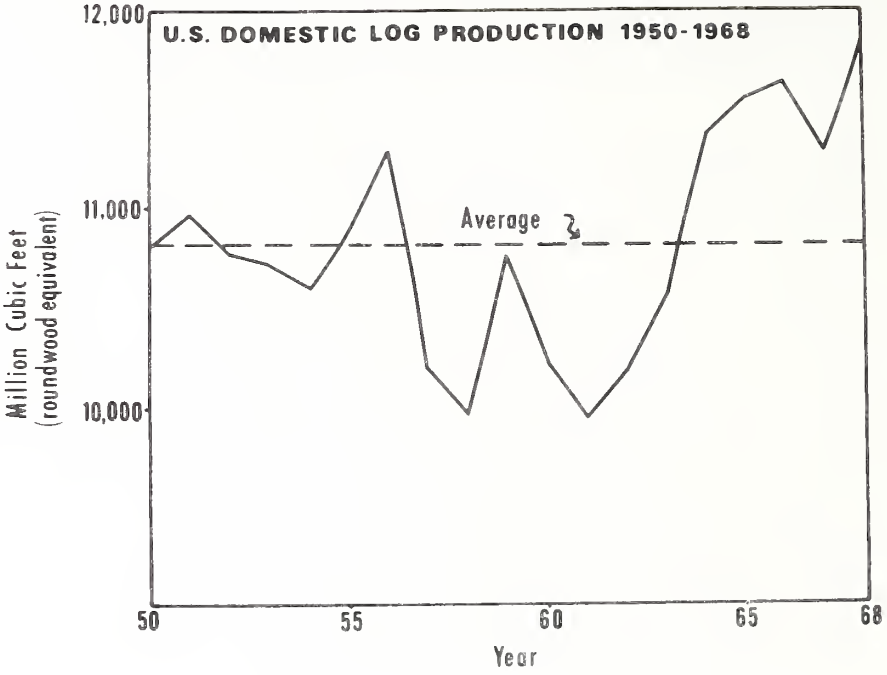


Figure 56.-U.S. domestic log production 1950-1968. The solid line represents the total production of timber in the United States and the dotted line represents the average production over the 1950-1968 period. Timber production has increased 9% over this period of time and 19% from its lowest point (1961). For comparison, agricultural production increased 11% over the same period and 14% from its lowest year, 1948 (Watt, 1968). Forest production data from Hair and Ulrich, 1969 (from Lugo, 1970).

The second step in the ecological solution is the management of individual systems. Decisions of management must follow the understanding of the structure and function of the system. You will recall that the crucial elements of ecosystem function are the sources of energy, the receptors and method and rate of cycling. Proper management take full advantage of these elements. For example, in forestry, high-intensity management is an expensive operation even if it increases yield. Figure 57 shows that when the quality of the environment is a consideration, this kind of forestry may be uneconomical Thus, proper forest management involves the closing of the mineral cycles. In a forest, certain species, which are not generally common, perform this function. Examples are: dogwood trees controlling the calcium cycle, epiphytes reabsorbing minerals from rain water, shade leaves storing minerals for long time periods, and root mats filtering wate that percolates through the soil. Ecological management sacrifices a small short-term yield in favor of those species which eventually make the management cheaper and healthie from an ecological point of view.

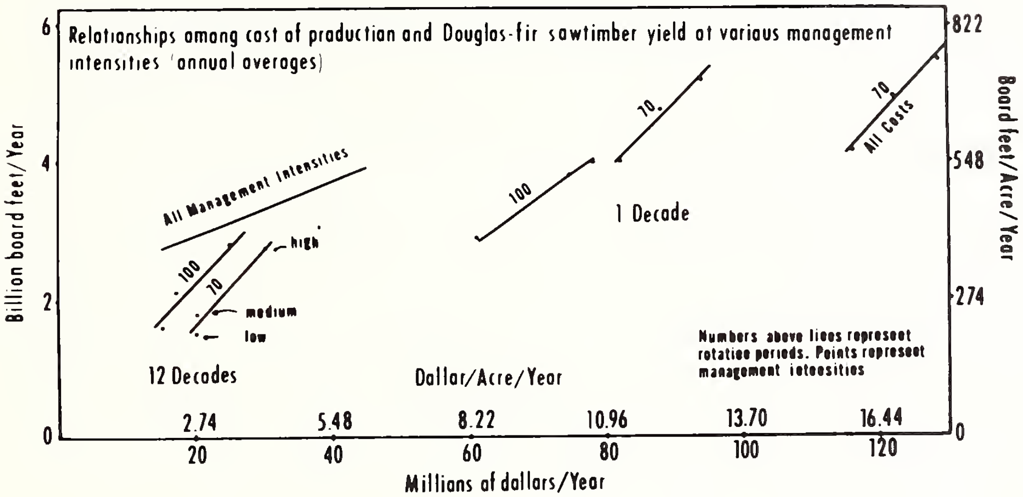


Figure 57.-The cost of production. Cost of production varies with management intensity (low, medium, and high), rotation period (short: 70 years, long: 100 years) and production rate (yield/decade and yield/12 decades). These data do not include the cost of preventing environmental deterioration (erosion, siltation, etc.), investments in forest research, forest fertilization, forest genetics, and increased yields resulting from forest fertilization. These costs were included in the line labeled "all costs". Research costs were calculated at $0.09/acre (Bethune and Clutter, 1969). Road costs to minimize erosion added $7,500/mile of road; $4,000/mile of stream was added to prevent stream erosion and loss of fish due to addition of debris (Jorgensen and Newport, 1969). Timber production was assumed to increase 30% over a six year period as a result of nitrogen fertilization and the cost of fertilization was $18.00/acre plus 7% interest with both production and costs calculated as average costs for a decade (Anderson, 1969). Costs of forest genetics were not available. Note that increasing production through fertilization and shorter rotation resulted in a 38% yield increase while costs increased 64%. When costs to protect the environment are added, the profitability of intensive management becomes questionable. (from Lugo, 1970).

Table 6 summarizes data on ecological management versus intensive management of sava ecosystems. This is a dramatic demonstration of what has been discussed about the value of ecosystem adaptations to local conditions. This kind of success might persuade man to adopt ecological management. The alternatives are clear: The spaceship is expensive and unreliable, spaceship earth is trouble-free at no cost. The choice is ours.

Table 6. - Production costs and yields of alternative forms of management on the African savannah (Henderson Ranch data, from Dasmann, 1964). Under ecological management, nature pays a large share of the "cost" of producing protein. When man intensively manages the same system in order to obtain a particular kind of protein (livestock instead of wild herbivores) the cost goes up and the net yield drops. Note that the gross yields of both management forms are similar.

YIELDS AND COSTS	ECOLOGICAL MANAGEMENT	INTENSIVE MANAGEMENT
Gross yield	$ 15,400.	$ 14,554.
Production cost	6,440.	13,138.
Net yield	8,960.	1,417.

CHAPTER III

HISTORY OF THE OCALA NATIONAL FOREST

The rising, red ball of sun hung on the horizon, touching the tops of the frosty ines with golden shafts of light as the sleek buck followed his doe through the October og in the valley. No wind stirred the leaves and they stopped to scent and sound the r after every few steps as they approached the mist-shrouded creek buried in a blanket oak and gum trees.

A mocking bird, roused from his night's perch in a low-lying myrtle bush, squawked sleepy protest and both doe and buck froze, motionless. The stillness continued un- oken, and once again they resumed their cautious, stately march. Only the sound of eir small, sharp hooves cutting the sand reached their ears as they passed beneath the rst huge live oak with its moss-draped limbs.

They stopped when a green and bronze spotted leopard frog leaped from the bank into e water with a loud croak, then paused again when the water lapped at their shiny, black oves.

The buck drank first as the doe stood watch, ears flicking back and forth as she anned the palmettos, the buttonbushes and small shrubs and trees of the forest under- ory. Then, as she lowered her head to drink, the silence was broken by the twang of bowstring and she jumped once, straight ahead, and died, as her blood mingled with e clear-flowing waters of the creek. The buck turned and cleared the nearest clump palmettos in a single leap. The white flag of his tail flashed once in the gloom neath the oaks and he was gone.

The bronzed hunter that waded into that cold creek to claim his kill and haul his ize home could have been a modern bow-hunter of the 20th century. But he was a mucuan Indian, one of those Hernando DeSoto described as being of "splendid physical pearance", and the time was some years before DeSoto logged those impressions in his urnal in 1539. Today, only the land and the name "Ocali" has endured. The Timucuans d all those before them are gone forever, victims of wars, diseases and the march of ite civiliation. Their fortified towns and cultivated fields, which led DeSoto to scribe them as "well advanced in civilization", passed into oblivion, as indeed has e meaning of the word "Ocali", which translates loosely into "fairland" or "big mmock". The history of the "Ocali" forest is long and rich with many man-made steries hidden beneath the sands of the dunes. But the natural history precedes man, ose first traces have been dated at about 3000 B.C.

Erly man-land relationships

Millions of years ago, as glaciers scoured the face of the North American continent, Forida periodically rose above and fell beneath the sea. During the Pleistocene, about 3,000 years ago, the land was inundated for many years and wave action formed bottom rpples much like those one sees at any coastal beach today. When the land rose above t sea for the last time, lapping water eroded successive ridges. Those ripples and rdges became the "Ocala Ridge," a line of rolling sand hills roughly parallel to the dstant Florida east coast with an elevation varying between 175 and 200 feet above sea lvel (see Chapter IV).

The first men to slog up those sandy ridges came to the area about 3,000 years ago. Gerally, they lived near the water, collecting molluscs, turtles and fish and hunting gne. Massive shell mounds remain to mark these living sites, some of which today are fr from water, an indication of how the St. Johns River and other streams changed their bnks in ages past.

The shell mounds, Pre-Colombian rubbish heaps, were treasured by modern, technologi- cl man who mined them, in the absence of rock, as foundation material for road building. Mny north Florida roads still rest on foundation of shell collected by ancient peoples.

Shortly before 2000 B.C., sediments filled some of these bodies of water, the supply of snails and other molluscs dwindled and waterfront settlements were abandoned. Raiding parties from enemy tribes killed the men and stole women and girls. Cannibalism may even have been practiced, as suggested by Jefferies Wymann, a scientist of the 1800 At any rate, the early residents declined as a result of natural and competitive pressur

Following the arrival of the Spanish Conquistadores in the 1500s and others in late years, the Big Scrub regions became solely Indian territory. Hot, dry infested with biting flies and mosquitos, the tangled scrub was hostile to the white settlers, who preferred the relatively fertile and more easily reached river banks and coastal areas.

Competition for space increasingly haunted the Indians, who warred among themselves and against white settlers for property rights. The Carolina Yamasses invaded and absorbed the resident Timucuans in the early 1700s, one group of indians known as the Oklawaha settling near the river which still bears their name, meaning "swamp."

The ecological principle of competitive exclusion, whereby one population annihilat another in the race for control of a common resource, whether space, food or whatever, eventually forced the Yamasses, the Oklawahas, and other tribes into exile or extinction before the onslaught of white settlers.

In 1766, John Bartram, a Philadelphia botanist, explored the St. Johns River banks for plants for London's Royal Garden. Several years later his son, William, returned to become the first man to accurately describe the flora and fauna of the "great scrub."

So accurate were William Bartram's observations that visitors today, using only Th Travels of William Bartram, can recognize many of the species of flora and fauna descr therein. Standing on top a high pines dune, they still can see Bartram's "almost endle view of a vast barren desert, altogether impenetrable ... with short, scrubby Oaks, Bays Yapon, Pinos and short laurel bushes."

The "altogether impenetrable" scrub nevertheless gradually yielded to the white ma onslaught, starting with huge Spanish land grants to loyal citizens such as F. M. Arredondo and Joseph Hernandez. In 1821, Andrew Jackson's government purchased Florida from Spain for $5 million and the territory was opened to settlers. Two years later, t Seminoles were banished to a south Florida reservation from which they continued to ran as far north as the Big Scrub on hunting expeditions. In 1835, R. B. Ker, penetrating into scrub areas formerly known only to the Indians, was shot at by a group of "renega Indians, but escaped to record the lake that still bears his name, discovered on his birthday.

Other rugged individuals unafraid of hardship claimed isolated homesteads within t scrub, turning loose scrawny Spanish cattle to compete with deer for the brittle wiregr and sedge. "Varmints - pumas, bears and wolves - took their toll of cattle and garden produce, but the settlers stuck it out and little by little, man's pressures began to affect scrub ecology.

"Piney woods rooters," or razorback hogs, uprooted and ate tender young pine seedlings and plowed the forest floor for acorns. Cattle grazed the tenderest shoots and grasses until some forage species disappeared from the scrub. Game trails became one-lane "highways" under the plodding hooves of cattle and hogs and iron-bound wagon wheel carved two-rut roads across the scrub. Waterholes became cooling and basins for hogs during long, hot summer days and myrtle bushes and scrub oaks became fly whisks for insect-pestered cattle.

Scanning a map of the Ocala National Forest today, the visitor finds areas such as "Pat's Island" and "Hugh's Island." Settled respectively by Patrick Smith and Hugh Stanaland, these longleaf pine-scrub oak "islands" became as oases in the relatively infertile scrub. Rows of beans, corn, squash and okra carved the only fertile soils of the scrub and pounding hurricane rains turned the clear creeks and streams into muddy ditches, carrying away what topsoil the little garden plots exposed.

The settlers waged a constant war against predators, shooting wolves and pumas whenever the opportunity arose. They rendered lard from bear's fat and smoked meat for dog food. Periodically, they banded together for wolf hunts, the last of which exterminated forever the Florida wolf in the 1800s.

During the Civil War, Federal and rebel troops marched and slogged across the scrub and one of the most unusual engagements in U. S. military history was fought along the St. Johns River and Lake George. Following a raiding expedition into Lake George, the Federal gunboat Columbine was ambushed by a small Confederate cavalry and infantry force. Commanded by Captains Dickison, Gray and McGahagin, the rebels surprised the Colombine at Horse Landing and successfully put her out of commission without the loss of one rebel soldier, perhaps the only time on record that a Federal naval vessel was captured by cavalry!

The post-Civil War depression was followed by an orange "boom" as planters learned to graft sweet Chinese oranges to the Spanish sour orange stock that grew "native" over much of central Florida. Palatka became a citrus brokerage and shipping center as steamboats plied the dark waters of the Oklawaha River, loading crates of oranges at the primitive landings. The riverboats also provided a source of sport for wealthy planters and northern "sportsmen," shooting alligators from the deck, a practice advertised in Harper's Weekly and other leading publications.

In 1879, the railroad came to Ocala and filled the handsome Victorian hotels with wealthy sportsmen, lured by the cosmopolitan atmosphere, the mild winter climate and the scrub's plentiful game. Lake Ker and Salt Springs became resort areas as the cacophony of human voices, children's cries and the elegant swish of ladie's crinolines obliterated the quiet sounds of nature.

During the hunting season, wagons with built-in dog boxes, drawn by sweating mules or horses, drew up at hotel curbs and took their loads of wealthy hunters. The air was redolent of fine tobacco and gun oil and the rising sun slanted off highly polished, knee-high boots and painted wooden wagon spokes as "darkies" drove their former masters over sandy roads. The eager yelps and cheerful cries that range throughout the forest held no hint of the disasters yet to come.

Old newspapers recall the freeze of 1895, when the "mercury dropped with unexpected and unprecedented suddenness... a few days later the groves looked as though a terrible plague had swept through them." Banks closed, fortunes vanished and citrus reigned no longer. Hotel gingerbread collected mildew and cobwebs, leather buggy seats cracked in the searing sun and those who had nothing else and no other place to go turned to the scrub for a living.

Alligators were hunted again, this time for the leather to make shoes, purses and belts. The larger alligators over 7 feet long were not molested because the horny buttons inside each chink in the hide made their skins unacceptable to the tanners. Therefore, older gators were left to perpetuate new stock, but eventually, of course, as age took its course, they passed on ahd the number of breeding stock declined. It gradually became less and less common to see an alligator in the wild.

Another practice widely followed was the trapping of fur-bearing animals during the winter months for their hides. Skunk, opossum, fox, bobcat and otter hides were all in demand and provided substantial winter incomes to a number of local families. During the "flapper" period when coonskin coats were popular, prime hides brought as much as $10 to 12 apiece.

These hides were usually delivered to tannery agents in a "green" or salt-cured state. Salt was also used in place of non existent refrigeration for the preservation of meat and whole families used to trek overland to New Smyrna Beach to camp for several weeks near the ocean to get enough salt to last the year.

Moonshine got its start in the scrub during that period when bonded whiskey became a rich man's pleasure and the tradition thus established remained to plague agents of the Tax and Alcohol Division years later during Prohibition. Individual stills turning out a barrel at a time made a fairly good grade of whiskey, although occasionally a poisoning would occur. Larger commercial stills up to 2500-gallon capacities were destroyed by "revenuers," who reportedly sought stills in the tangled recesses of the Fern Hammock Springs, Crooked Sapling and Mormon Branch areas.

The scrub therefore experienced a lawless period and became a frontier of its own within the state. Crackers who lived in the area considered the land and game theirs and resisted prying tourists and government agents. A thriving trade in hides, furs and illicit whiskey linked any number of meager homesteads to surrounding communities.

Into this depressed region strode a new breed of entrepreneur, financiers who remembered the fortunes lost in the "Great Freeze" and were determined not to fail. Subscribing to no rules of conservation, they exploited the land and its resources as the discovery of phosphate and the expansion of timber and naval industries produced new markets. (Naval stores describes a large variety of pine by-products, including "teppentime," creosote and natural resins.)

They hauled the longleaf pine to mills near Lake Dorr and felled the big cypress trees along Lake George and other waterways wherever they could float their steamboats and barges. Winching felled logs out of the swamps, they built hugh log rafts and floated the timber "down" the north-flowing Oklawaha River to Palatka sawmills. Both river swamp and high pinelands resounded to the chuff and whistle of the steam-drive donkey engines and the crash of falling timber. In less than twenty years, the stately pine forests and the virgin stands of cypress were reduced to hugh piles of sawdust and sawmill "tailings."

Sand pine, the dominant species over much of the area, wasn't subject to this exploitation. Not until the 1930's was a method devised which made it a feasible source of pulpwood. Much of the longleaf pine logging and nearly all of the phosphate mining likewise occurred outside the present-day boundaries of Ocala National Forest, but the promise of destruction that annihilated nearby habitats threatened the scrub also. Unscrupulous destruction of significantly large areas of forest so altered prevailing natural systems that climate was adversely affected. Soils eroded and leached out, the ground water table was lowered and the public began to awaken to the realization that such wholesale mismanagement could not continue.

A new movement coined the term "conservation," and powerful voices favoring this concept began to be heard in prestigious places. For the scrub, a new way of life was dawning and although it was too late to save the wolf and the puma, the scrub itself escaped the exploiters' shovels and axes.

The U. S. Forest Service as Guardian of the Ocala National Forest

Florida Republican Herbert L. Anderson was one of those concerned about the fate of the scrub and in 1908, succeeded in having Congress declare the region of eastern Marion County between the Oklawaha and St. Johns rivers a national forest. Conservation-minded President Theodore Roosevelt signed the bill setting aside the "Big Scrub" as the first national forest east of the Mississippi River on December 8, 1908, thus effectively putting the scrub under the protective umbrella of the fledgling U. S. Forest Service.

Management policies essentially adhered to the charge made by Secretary of Agriculture James Wilson in 1905 to Chief Forester Gifford Pinchott, to "... see to t that the water, wood and forage of the reserves are conserved and wisely used ... ll the resources of forest resources are for use, and this use must be brought about in thoroughly prompt and business like manner, under such restrictions only as will insure he permanence of the resource ..." The 441,925 acres of the new Ocala National Forest id not include the privately owned longleaf pine islands nor railroad grant lands nor tate and school sections.

In 1927, President Calvin Coolidge declared the Forest a distinct and separate unit f the Forest Service, placing it under the management of a separate ranger team. As cala thrived, campers, picnickers and sportsmen were once again attracted to the Forest, ut the Stock Market Crash of 1929 coupled with the onslaught of the Mediterrean fruit ly on the Florida citrus soon erased recreational use of the Forest.

During the Depression years, Civilian Conservation Corps (CCC) workers, in a nation-ide program, developed recreational facilities on public lands. In the Forest, their fforts produced campsites, picnic grounds and shelters, roads and other improvements, ost notable of which was development of the Juniper Springs recreational area. Barely ecovered from a searing fire that scorched 21 miles of the forest from the Oklawaha River o Lake George, the area was transformed from a tangled jungle surrounding a log-choked pring into a resort that became the most popular Forest Service recreation area in the outh following its opening in 1936.

Managing the Forest's assets also entailed protection of the wildlife and in 1930, he Ocala National Wildlife Refuge was begun. Two years later, it involved 78,000 acres hat fell under a comprehensive fish and game management program administered through the . S. Bureau of Fisheries, the Forest Service and the State Game and Fresh Water Fish ommission. The refuge, now 262,500 acres large, shelters approximately 7,500 whitetail eer, one of the largest herds in the southeast, and provides habitat for rarer species hat are seldom seen - the Florida panther or puma and the black bear, both of which are rotected from hunting. Deer hunters eagerly pursue the elusive deer during the annual, anaged hunt, begun in 1938 by the Forest Service and the Florida Game and Fresh Water ish Commission.

The same fire that scorched the Juniper Springs area demonstrated the severity of he fire hazard in the Forest and the need for fire control. That fire, in 1935, burned 1 miles in 3 hours, consuming 10,000 acres, then turned with the wind and burned 25,000 ore acres in just one hour. Five fire lookout towers were built in the Ocala National orest, only one of which is in use today. Observers in airplanes have been found to be much more efficient way of quickly detecting fires. Fortunately, fire control methods ave improved greatly over the years. Whereas there are approximately 123 fire per year n the Forest, only about 700 acres are burned (31% caused by lightning and 69% caused y man). This may be attributed to early detection and a fire control organization built round crawler tractors with large fire plows, tank trucks and war surplus bombers which rop fire-retardent liquids on the fire. Mature sand pine trees are susceptible to fire nd are destroyed by fires which would have little effect on longleaf pine. However, he small hard cones require the fire's heat to open them and trigger the release of seed. his results in a new stand as the seeds fall on bare mineral soil.

To counteract the ravages of fire, the U. S. Forest Service embarked on a reforesta-ion program. The Clarke-McNary Act of 1932 authorized the purchase of the longleaf pine "islands" as a source of seedlings for stocking barren areas and helping prevent sheet rosion and improve rainfall infiltration. Sand pine cones are collected and heated in vens to artificially release the seeds. The seeds are then treated with chemicals to eter small animals from eating them. These seeds are then sown by helicopter in areas n which the site has been prepared by heavy equipment. Thus, the sand pine forest is egenerated by duplicating the natural fire mechanism.

Fire is a two-edged sword which can either be destructive or beneficial. In some instances the U. S. Forest Service intentionally sets fire in the Forest. These are called prescribed burns and are carefully planned to take advantage of favorable moisture and wind conditions to ensure a relatively cool fire. These prescribed fires duplicate the lightning-fire climate under which longleaf and slash pine evolved.

Correctly performed, prescribed fire is beneficial. It stimulates the production of native plant foods (for wildlife) that otherwise might be inhibited by the build up of a thick mat of pine needles and forest litter. Removal of this fuel by a relatively cool prescribed fire prevented the accumulation of fuel which at a latter time may be accident set fire resulting in the destruction of the slash or longleaf pine. The prescribed burn also reduces the growth of low (dollar) value competitors, such as scrub oaks, with no damage to the pines. This type of fire management results in the open park-like areas observed on the longleaf islands.

In the past, the U. S. Forest Service issued special permits authorizing the construction of recreational residences on government lands. However, following World War II, the public demand for recreational space precluded consideration of private users and the permit policy has been discontinued. Five recreational camps are still in use - the Youth Conservation Camp at Lake Eaton, Deer Lake Girl Scout Camp, Mill Dam Lake Kiwanis Camp and two 4-H camps at Doe and Grasshopper Lakes, all sponsored by public organization and service clubs.

Through the protective policies enforced by the U. S. Forest Service, the Ocala Natio Forest has thrived and resisted wholesale exploitation by private and corporate interests Home of the world's largest loblolly bay tree (Gordonia lasianthus), turkey oak (Quercus laevis) and sand pine (Pinus clausa), the Forest still bears resemblence to that William Bartram described 200 years ago as "altogether impenetrable ... with short scrubby Oaks, Bays, Yapon, Pinos and short laurel bushes."

The Ocala National Forest Today

The Ocala National Forest today is bounded by Lake George and the St. Johns River on the east, State Highway 42 to the south and the Oklawaha River on the north and west (figure 21). This area encompasses 430,349 acres of which 64,058 acres are in private ownership, leaving 366,291 acres in public ownership. The U. S. Forest Service engages in land purchase or transfer negotiations in order to acquire private lands within the Forest boundaries. A recent substantial purchase was the Domingo Fernandez grant lands lying west of the St. Johns River and north of State Highway 42, which added about 5,000 acres to U. S. Forest Service lands.

National forests are managed under the multiple-use concept which seeks to coordinate resource management so that areas of land produce a combination of values that best serve the American public's need. Much of the forest that you visit will be used for a combination of uses such as growing timber, while it also provides a home and food for wildlife In other areas a single resource such as recreation may be the primary management objectiv to the exclusion of management for other resources such as timber. An example of this is a classified scenic area where recreation is the main objective and no timber management is practiced. Each area of the Forest is examined to see what resources will be utilized to give the greatest benefit to the American public.

Sustained yield means that the forest resources are managed to provide services and products (recreation, wood, etc.) at an optimum level so that we won't exhaust or deplete the forest. This will insure that there will be a never-ending supply and our children and theirs can continue to enjoy the fruits of the forest. During 1971, a detailed study was prepared that considered all of the resources available on the Ocala to see how the Forest could best meet the needs of the American public. This plan emphasized the tremendous potential for outdoor recreation made possible by the favorable year-round climate. The Ocala National Forest is one of America's great playgrounds. The forest is managed so that it can best serve the steadily increasing members of Americans seeking relaxation in the out-of-doors. The attractions available to you range from family picnic units to remote canoe streams and extended hiking trails. There are 20,346 acres of waterways besides Lake George to attract the fishermen and boater or canoists, ranging from the coffee-colored Oklawaha River to crystal-clear Alexander Spring which sends 78 million gallons of water per day to sea through the St. Johns River.

An annual fall hunting season from November to late December attracts hunters from several states in pursuit of deer, turkeys, wild hogs, squirrels, rabbits, quail, dove and ducks. The U. S. Forest Service maintains 15 hunt camps (figure 58). All hunt camps and almost all fishing areas can be reached on the 325 miles of paved and graded roads maintained in the Forest.

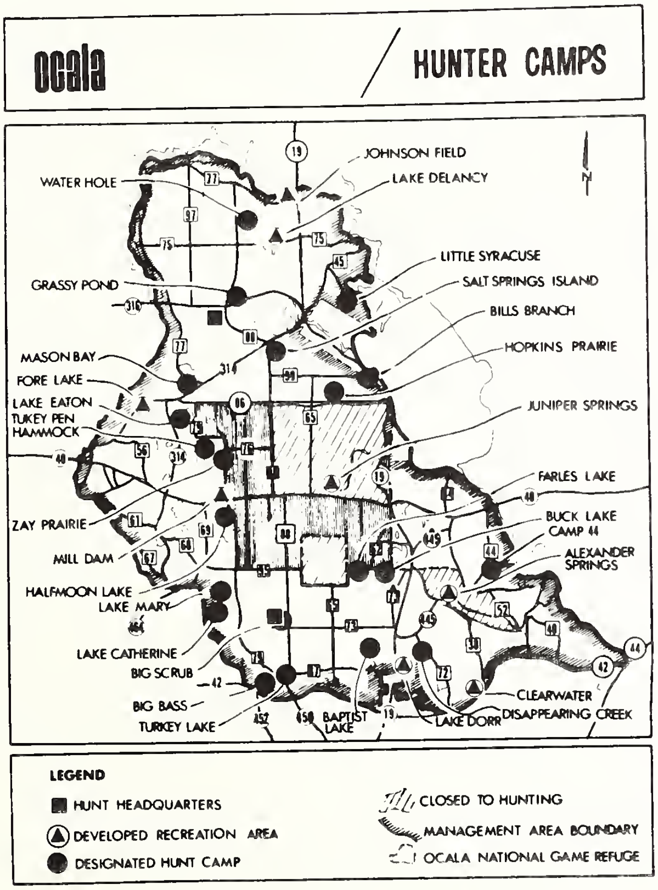


Figure 58.-Hunter camps and developed recreation areas in the Ocala National Forest.

Not everyone comes to the Forest to hunt or fish, of course, the majority preferring the quieter pastimes of camping, hiking, swimming or the arts of sketching or photography. Constant attractions to these naturalist visitors are the diverse habitats with their different species of wildflowers and indigenous wildlife. Over 200 protected animal species, some of which the Burea of Sport Fisheries and Wildlife list as "rare and endangered," make their homes in Forest habitats.

An "endangered" species is one that has experienced significant decline as a species to the point it warrants protection and recognition as being close to extinction in its natural state. A "rare" species is one restricted to small, specific and usually virgin habitats beyond the limits of which it could not exist. Its numbers are quite small and as its preferred habitats are usually far removed from human traffic, it is rarely seen by the casual visitor.

Representative of a rare species that may inhabit the Ocala National Forest is the Florida sandhill crane and its seasonal counterpart the greater sandhill crane. The Florida sandhill crane, *Grus canadensis pratensis*, is a permanent resident of the wet Florida marshes, but the greater sandhill crane only winters on those same marshes. A gaunt, grey ghost of a bird with a small red skullcap, the sandhill crane may be seen occasionally by the early rising camper on one of the wet prairie marshes. The rattling, rusty cry he emits as he spreads his great wings and departs can raise your hackles on a foggy, misty morning.

Locally rare, but classified endangered, is the Everglades kite, *Rostrhamus sociabilis plumbeus*, which is restricted to freshwater marshes by the availability of its specific prey, the freshwater Mystery snail, *Pomacea paludosa*. Although the Mystery snail abounds in the freshwater ponds and marshes in the Forest, the kite is only rarely seen, probably due to the destruction of habitats between the Forest and its last great refuge, the Florida Everglades.

The Southern bald eagle, *Haliaeetus l. leucocephalus*, also classified endangered, is a year-round resident of the Ocala National Forest that can occasionally be seen by the visitor. Eagles stay close to water, preferring open bodies of water such as flatwoods, ponds, lakes and marshes to narrow, swift-running rivers. They usually build their five-foot diameter nests in large, old pine trees, from which they range outwards in search of fish and game for the eaglets, usually two in number.

A favorite stunt of the eagle is to pick on the osprey, *Pandion haliaetus carolinensis* a species that is considered rare and endangered over much of his former range, although not in Florida. The eagle will soar at great heights over a lake, watching the osprey, a fisherman, as he cruises. When the osprey dives to grasp a fish loafing on the surface, the eagle lets him rise and begin to fly away with the fish. Then, folding his wings, he drives down on the hapless osprey, screaming his war cry, usually causing the osprey to drop his prize which the eagle recovers in midair. Thus does the national bird save himself the indignity of wetting his regal feathers!

Bachman's warbler, *Vermivora bachmaii*, a small yellow-breasted bird with a black bib, is officially listed as endangered, although listed in Peterson's Field Guide to the Birds as possibly the "rarest North American songbird today." Inhabitant of southern river swamps, his choice of the Forest habitat would probably lie along the flooded Oklawaha River banks and he would remain unseen by the average visitor unwilling to penetrate their tangled growth. Reasons for its decline are obscure, but probably a significant factor has been the destruction of favorable habitats.

The increasing development of contiguous private lands representing significant habitat destruction is a factor beyond Forest Service control that nevertheless exerts ecological pressures on the various Forest habitats. As surrounding lands become developed, potential recreational space is removed from public use, the human population increases and in response to a need for recreational space, increasing visitor pressures bear on the Forest. In addition, wildlife, displaced from its natural habitat by development, seeks relief in the protected habitats of the Forest. As a result, the intruding species enter into a competitive situation with the resident populations which may result in artificial stresses on the natural equilibrium of the "balance of nature."

The Florida panther, Felis concolor curyi, is one species capable of fleeing man's developments to seek refuge in the Forest. Fully protected by state law, the panther is listed as endangered and probably sunstains a viable population only in the Florida Everglades. Panthers, once a significant factor in control of deer numbers, probably exert little pressure on the deer herd of the Ocala National Forest.

More likely to endure development so long as direct harassment is precluded is the American alligator, Alligator mississippiensis, listed as endangered. There is a considerable alligator population in the Forest and it is not unusual for the observant visitor to spot one occassionally, particularly along remote river and creek banks. Alligator exert a significant control during drought periods as their wallows are generally the last repository for water in the flatwoods habitats. The Forest, of course, with its numerous springs and spring-fed creeks, is less susceptible to severe water shortage than areas less well endowed with water resources.

Additional species, while not particularly rare or endangered, are uniquely attractive to the Forest visitor naturalist. Some of these are the Florida scrub jay, a bold and easily tamed resident of scrub habitats, the shy and colorful summer tanager, the ruby-throated hummingbird and the limpkin, resident of the river swamps.

For the amateur herpetologist, there is an abundance of turtles, lizards and snakes to be observed. Rarely seen, but probably fairly common is the harmless burrowing Florida worm lizard, Rhineura floridaus, found most often in the palmetto-rosemary scrub. Equally common but seldom seen is North America's deadliest snake, the coral snake, Micrurus f. fulvius, which closely resembles the harmless scarlet king snake, Lampropeltis e. elapsoides. The neophyte naturalist can easily distinguish between the two by recalling this ditty: "Red and yellow, kill a fellow; red and black, friend of Jack." This serves to remind one that the red and yellow bands of the deadly coral snake adjoin one another, whereas red and black bands adjoin one another on the color pattern of the king snake.

Two more of America's four poisonous snakes reside in the Forest, the rattlesnakes, Crotalus sp. and the water moccasin, Agkistrodon piscivorus. As might be suspected from his name, (Pisces) fish make up a significant part of the moccasin's diet. The pigmy rattlesnakes, Sistrurus sp., differ mainly from other rattlesnakes in size and the number of plates on top of their heads.

A good rule for the woods-roaming Forest explorer is to proceed slowly and never put hand or foot where it can't be seen. Most experienced naturalists feel the average snakebite case occurs as the fault of the person involved being careless - either poking hands into holes and logs, walking too fast to see the well-camouflaged snake or shoving through brush, particularly palmetto thickets, where the feet cannot be seen. Another good rule in the woods is never step over a log or stone - always step on it, look over, and then step down.

The summer visitor will be quickly reminded of his insect repellent if he strays far from developed campground sites. The Forest is still home to mosquitoes and biting flies that, coupled with heat and dust, reportedly caused the departure of the star actor in the original filming of Marjorie Kinnan Rawlings' "The Yearling." Rumor has it that Spencer Tracy, originally cast in the role of "Penny Baxter," found the heat, dust and insects so intolerable he ordered an Ocala taxicab, loaded aboard his duffle and had it drive him all the way home to California! The glaring heat of the summer sun is relentless on the scrub forest, only the barest whisper of a breeze stirring the pine canopy as the buzzing drone of cicadas intensifies the monotonous somnolence of midday. That is a time for enjoying the 74-degree-cool waters of one of the public or private spring-fed swimming holes in the region!

The ability to seek relief from heat, from boredom and experience other events and habitats is one of the attractions the Ocala National Forest holds for the repeat visitor It takes more than one short visit to become truly knowledgeable of the Forest's diverse habitats, for instance.

The sand pine is the dominant plant species of the scrub habitat, but an individual understory growth is also characteristic of this community. Dark-green rosemary shrubs, looking not unlike inverted shaving brushes, twisted staggerbush and scrub live oaks and low-growing saw palmettos are all found beneath the pine canopy. Wax myrtle, easily identified by its pungently aromatic leaves, also persists beneath the canopy.

The sand pine, due to its small bole diameter, is the principal pulpwood crop. Growing to only eight inches diameter at maturity, the sand pine has a relatively short rotation period of 40 years, meaning that following harvest, a stand can be ready for reharvesting from the same site in 40 years.

The longleaf pine islands are so named because they are surrounded by a sea of sand pine. They cover 16% of the Forest and are no longer being harvested for timber. The slow-growing longleaf has a regeneration of about 120 years on the sandy ridges and pocke of Norfolk sand where it is prevalent. The islands have open park-like qualities and are managed to protect and enhance their attractiveness while providing quality hunting areas

The pine flatwoods habitat, 11 per cent of the Forest area, makes a significant contribution to the total timber harvest. Species characteristic of this habitat are the dominant slash pine and the less common loblolly or oldfield pine and the pond pine, plus small amounts of oak. Understory species are generally small herbs, such as the Florida huckleberry and grasses - wiregrass, chalky bluestem and sedges. The pine rotation perio of these low, wet Leon soils where scattered ponds abound is generally about 80 years.

Hardwood sawtimber is cut from swamps occupying only 5.5 per cent of the Forest area This hardwood becomes either sawtimber or veneer. The characteristic swamp species, whic have a rapid growth rate on the Portsmouth soils, are bays, blackgum, oaks, maple, elm, hickory, magnolia, sweet gum, cypress and pond pine.

The open prairie is the last generally recognized habitat. Underlain by Leon-type soils sealed by water-impervious organic hardpan, these open grassy flats often become shallow lakes during rainy seasons. While not contributing an intrinsic cash crop in their own right, the prairies are invaluable as wildlife habitat and provide year-round recreational uses. Graced in spring by myriad wildflowers, the prairies support a divers and interesting wildlife ranging from the tiny burrowing owl to the invader from Texas, the nine-banded armadillo. The visitor driving onto one of the prairies can easily visualize himself on African safari or wagontrain trek across the American midwest, with the dominant background of grasses punctuated by an occasional flat-topped pine tree or cypress snag.

An expansive region of huge diversity, the Ocala National Forest truly has something to offer the most discriminating interest, ranging from skin-diving in spring-fed cisterns to photography of wild fauna and flora. Like any natural resources, the Forest resists packaging and delivery to the consumer, depending upon the interest of the visito to spark exploratory energies.

CHAPTER IV

THE GEOLOGY OF THE OCALA NATIONAL FOREST

troduction

The Ocala National Forest is not as simple geologically as one would presume from e dominance of sand pine scrub and the long leaf pine-turkey oak vegetation communities. contrast to the extensive xerophytic forests of considerable geologic antiquity chara- erized by many endemic (native) species of plants and animals, on the boundaries of the st, north and east are the lush swamp forests of the Oklawaha and St. Johns rivers. ese low swampy areas have a fascinating geological history related to changes of climate d sea level during and just prior to the great "Ice Age".

The "Ice Ages" were periods in the Pleistocene when the earth cooled and a vast amount the oceans' waters were frozen in the polar icecaps. During an ice age, the sea level s lower and glaciers crept southward over the northern United States. Between these per- ds, warming occured and the great polar caps replenished the seas and the water level se. The warming and cooling of the earth, together with the successive rising and fall- g of the oceans have had a profound effect on the Floridian penninsula. Earlier in apter II we described the conditions which fostered the accumulation of the carbonate eletal material of small marine animals (see pp. 53). This massive accumulation of rbonate ($CaCO_3$) limestone is close to a mile in thickness in some places. Due to sands d clays washing in during the formative period, the limestone is stratified in layers th these non-carbonate materials in between. The oldest known limestone in the state the Ocala limestone which was formed around 58 million years ago. It was exposed by eat upheavals in the region of Ocala and Silver Springs where it may still be observed.

A veneer of pure, medium to fine paleodune (old dune) sand forms a surficial blanket er most of the area of the Ocala National Forest, figure 59. It directly overlies ghly porous, permeable sand, gravel and clayey sand. It is these two generations of sands at have resulted in the distinctive hills with poor soils, high internal drainage and w water holding capacity upon which the xeric forest known as the Ocala Scrub occurs. e true scrub is developed only on paleodunes, but this occupies an area more than 35 miles ng and 15 miles wide. This is one of the largest and best developed relic dune fields the southeastern United States and is also the site of the world's largest stand of sand ne.

That the soils and vegetation of the Ocala Scrub are developed upon paleodunes was cognized by botanist, Albert Laesslae (1958). Kurtz (1942) had earlier interpreted is scrub as being developed upon residual sand soils. It is true that there are many eas, even within the paleodune field, where paleosoils developed upon older sand, gravel d clayey sands are at or near the surface but invariably these areas are forested by a ng leaf pine-turkey oak community. The frequency of occurrence of the scattered small ands of turkey oak within the scrub increases westward from Lake George.

The geological history of the Earth, as now interpreted, is based upon evidence eserved within the rocks and aggregate deposits of earth materials and the relationship these masses to each other and to the landscape. It would be a mistake to disassociate e story of the Ocala National Forest from the factual evidence for interpretation. Thus e geological history of the Forest is discussed under the headings of stratigraphy, ructure and physiography. Stratigraphy is the study of rocks including unconsolidated dimentary deposits. Structure is the relationship of the masses of earth materials to ch other, including the fracture patterns resulting in joints (breaks in the rock) and ose breaks along which recognizable displacement has occurred, i.e., faults. Physio- aphy is the study of the nature and origin of the landscape and is related to both ratigraphy and structure of the underlying earth materials. The sculpturing processes weathering and erosion are, in part, controlled by these factors. Finally, erosion and position is controlled by the relief of the land, runoff and the level of the sea.

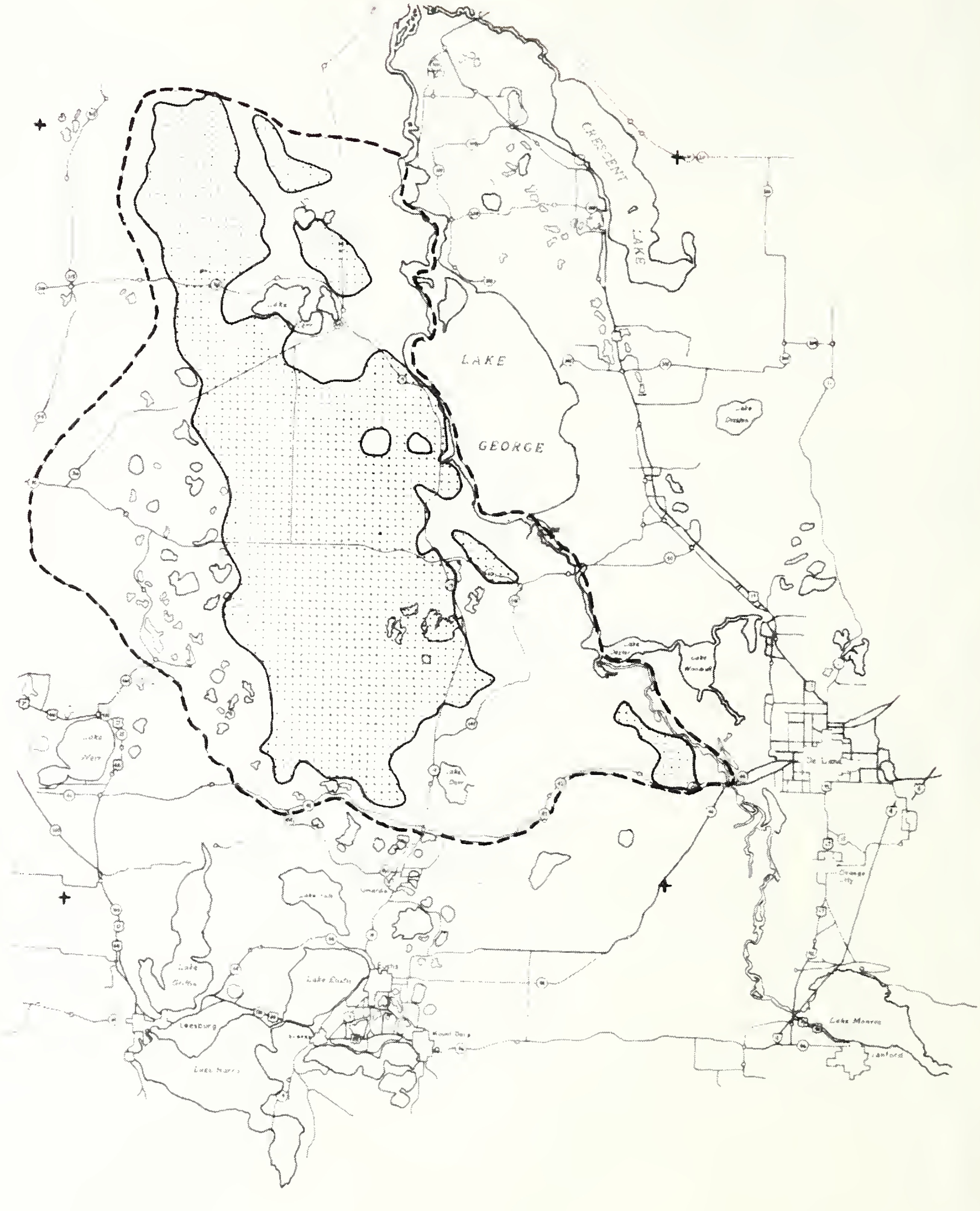


Figure 59. - Pleistocene sand dune field of the Ocala National Forest.

The age of the earth is estimated to be over 3,200 million years based on radio-ogical dating techniques. The geologic time scale units, as referred to in the following iscussion, are all subdivisions of the Cenozoic which represents only the last 60 million ears or so of the earth's history. Subdivisions of the Cenozoic are as follows along ith approximate age boundaries in years:

Quaternary	Recent	
		Began 10,000 years ago
	Pleistocene =	"Ice Age"
		1 - 3 million years
	Pliocene	
		13 million years
	Miocene	
		25 million years
Tertiary	Oligocene(not represented in Forest)	
		36 million years
	Eocene	
		58 million years
	Paleocene(not exposed in Forest)	
		63 million years

tratigraphy

Six distinctive sedimentary masses influence the landscape, soils and hydrology ithin the area of the Ocala National Forest. They are (1) the Ocala Limestone, (2) awthorne Formation, (3) "Citronelle Formation," (4) unconsolidated fossiliferous clays nd sands of the Oklawaha Lowlands, (5) paleodune sands and (6) the near-Recent fresh ater shell marls, sponge spicule clays, peats and mucks of the Oklawaha and St. Johns iver valleys. The areal distribution of these materials is shown in figure 60.

The Ocala Limestone is the oldest formation and it underlies all of the forest. It an be seen outcropping northwest of Eureka on the east bank of the Oklawaha River and in rainage canals at a camp development. All of the springs within the Ocala National Forest ssue directly from the Ocala Limestone. This limestone aquifer can be examined at a hallow depth by scuba diving. The most conspicuous underwater outcrop and five known nderwater exposures are plotted in figure 61.

The Ocala Limestone is a permeable, relatively pure calcium carbonate deposit of ocene age, 40,000,000 years or so old. It consists of a multitude of the skeletal emains of marine shelled animals. The dominant flow of water in this limestone is via avernous channels dissolved along joints and faults. The many lakes to the east and west f the high north-south sand hill ridge dividing the Forest are due to the dissolving action f filtering rain on this carbonate formation. It should be noted that the align-ent (the long axis) of the lakes has been controlled by the factures in this formation. he lake basins are solution depressions in an advanced stage of evolution. It is robable that they originated as simple collapse sinkhole depressions.

Lake George owes its origin to solution of the Ocala Limestone. In the area of Lake eorge and in the adjacent low sand hills the upper surface of the Ocala Limestone is at t above sea level as it also is in the sand hill karst (karst refers to major limestone reas such as Florida and the Yucatan Peninsula) lake area to the west in the area of Lynn ear the Oklawaha River. Under the high sand hill ridge that divides the Forest, the pper surface of the Ocala Limestone is known to occur at a depth of 150 to 300 feet below ea level. It is this difference in the elevation of the top of the soluble aquifer that as determined the development and occurrence of the springs and sinkhole lakes as well s the residual sand hills.

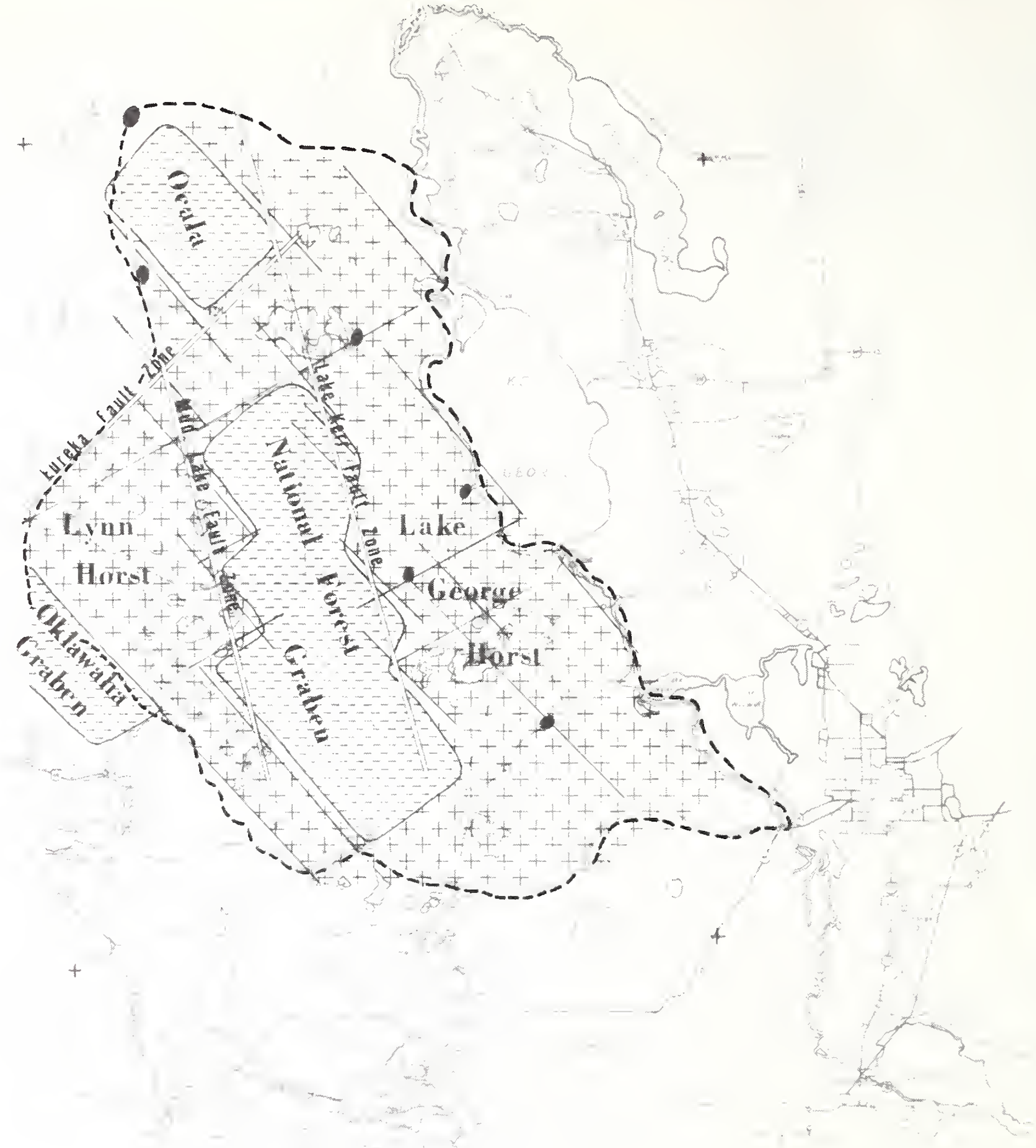


Figure 60.-Structural map of the Ocala National Forest.

● - Eocene limestone outcrops

// - Fault zone

/ - Tear fault of an echelon fault system

-- - Downfaulted Blocks or Grabens, top of Eocene limestone-150 feet or more MSL

+ + + - Uplifted Blocks or Horsts, top of Eocene limestone at sea level or above

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The Hawthorne Formation is a poorly defined stratigraphic unit. It has been a catch-all formation for diverse phosphatic sands and clays. As used in this book, the name is restricted to consolidated phosphatic clay, sand, limestone and dolomite, which in some areas of the Forest are found to be over 100 feet thick in the subsurface. The only good outcrop of true Hawthorne Formation in the area of the Forest is in the large sand burrow pit east of the Eureka Lock. Here the brilliantly colored orange, brown, tan and red sand and gravel of the "Cirtonelle Formation" can be seen resting unconformably over and around pinnacles of Hawthorne limestone and consolidated green sandy claystone containing a Lower Miocene marine fauna about 25,000,000 years old. Buried topography below the "Citronelle Formation" is typical of the area and explains the discontinuous and heterogeneous occurrence of the Hawthorne Formation as found in core borings.

The "Citronelle Formation" consists of sand and gravel intermixed with clayey materials. The formation is the most colorful in the State of Florida with orange being dominant. The color, however, is not a primary feature of the deposit. It is the result of laterization, a soil development process, which involves leaching and the precipitation of iron. The oxidized crusted iron gives soil a red or orange color. The "Cirtonelle Formation" underlies all of the sand hill area of the Forest but over much of the area it has been masked by surficial dune sands, see figures 59 and 60. The thick residual sands above the colorful subsoil zone is also characterized by iron staining. In the current classification of Florida agricultural soils this thick residual sand is termed Lakeland soils.

The "Citronelle Formation" has been interpreted as a riverine deposit but the linear distribution, complex bedding, presence of oblate sphereoidal "beach pebbles" and the occurrence of shrimp (Callinassa) burrows suggests a prograding marine shoal built southward along the axis of the peninsula. Marine molluscan fossils have been collected from the "Cirtonelle Formation" at the large borrow pits at Interlachen, Clermont and Lake Wales. The concept of a prograding linear delta 10 to 15 miles wide is not significantly different than the shallow prograding shoal inferred above. The word delta implies that the predominant transporting agent of the coarse clastic sediment was a stream whereas the use of the word shoal infers littoral processes as the pre-dominant transporting agent. We recognize both transporting agents were highly active during the time of deposition of this unusual formation. In fact, most of the sands of peninsular Florida were transported southward at this time. Despite the absence of identifiable index fossils, the age of the formation is reliably fixed since it lies above the post-Middle Pliocene. It is probably Upper Miocene in age and is something over 13,000,000 years old.

Clayey, green sands that are, in places, highly fossiliferous occur in the Oklawaha and St. Johns River valleys. These unconsolidated to semi-consolidated materials occur n linear basins underlie the poorly drained low pine flatwoods associated with the river owlands. It is probable that this deposit is Late Pliocene or Early Pleistocene which would make it less than 5,000,000 years old.

The surficial dune sand (figure 59) that underlies the Ocala Scrub is variable in thickness and occurrence. It is best developed west of the St. Johns River and Lake George. Topographic expression of the dunes as relief features can still be recognized especially in areas where the vegetation has been removed by fire (figure 62). A very nfertile fine sand soil, the "St. Lucie," has developed upon the dune sand.

Laesslae (1958), has interpreted the vast paleodune area of the Ocala National Forest s being associated with the period when the water was 25 feet higher than now. He elieved the dunes migrated west, southwestward and upward from a coastal shoreline along he St. Johns River. We now know that the St. Johns was an estuary at the time of the 25 oot stand of sea level and that the east coast of Florida, representing the high energy tlantic seashore, occurred much farther eastward near the present coast.

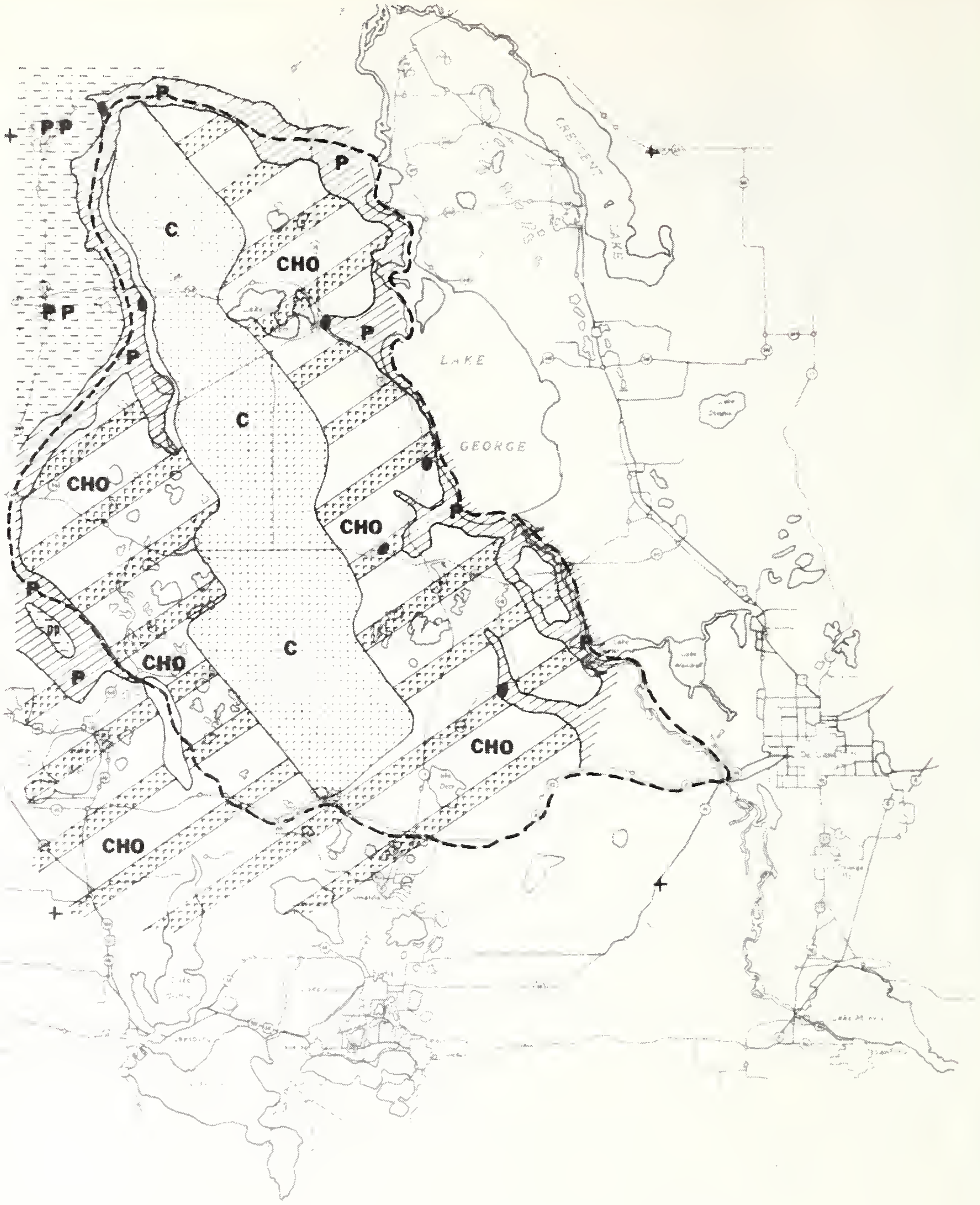

Figure 61.-Geologic map of the Ocala National Forest.
Legend:

P - Peat, muck, clay and fresh water marl-Pleistocene-Recent

PP - Sand and clay, marine fossils - Plio-Pleistocene

C - Citronelle Formation - sand, gravel and clay - Miocene

CHO - Citronelle Formation, Hawthorne Formation and Ocala Limestone; sand, clays, limestone, mostly Citronelle sand and gravel below surficial sands

● - Ocala Limestone outcrops - Eocene

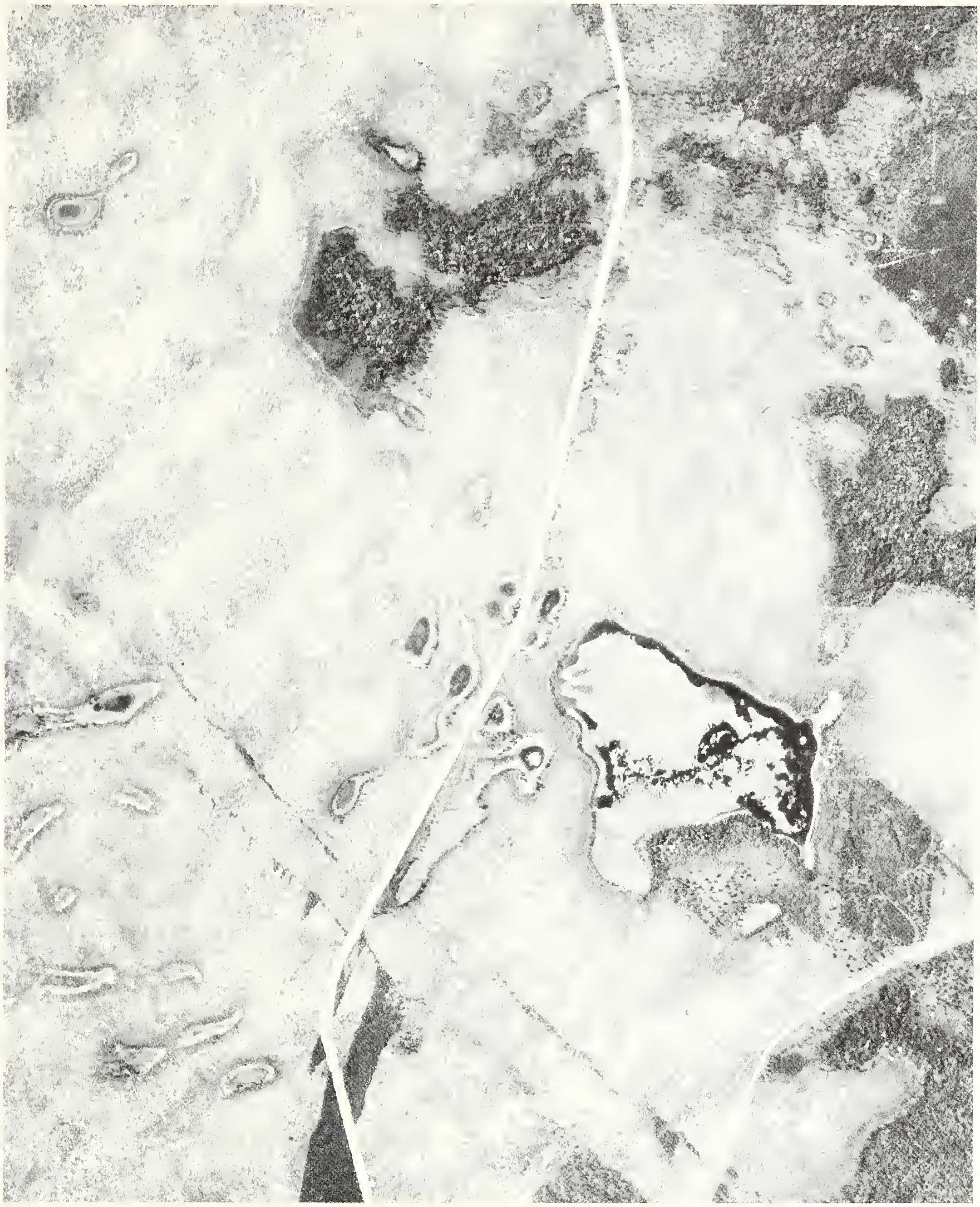

Figure 62. - The Pleistocene sand dunes exposed by fire removing the overlying xerophytic communities. Note the parallel fault lines running diagonally on the right-hand portion of the photo. The faults stand out because of moisture soil conditions which supports a mesophytic forest resistant to severe fire damage evident in the sand pine. The dunes run perpendicular to the fault lines. (photo credit - U. S. National Archives)

At many places in the Ocala National Forest the paleodunes are now flooded as at Farles Prairie. This evidence indicated the paleodunes were not associated with a high interglacial stand of sea level but that they represent extreme xeric conditions result g, not only from climatic change, but also a lowering of the regional water table in response to a glacial lowering of sea level. The dunes in the Ocala National Forest were probably active at several times during the continental glacial stages of the great Ice Age during the last 900,000 years.

Possibly the most fascinating geological materials in Marion and Lake Counties are the very young fresh water shell marl, sponge-spicule clay, peat and muck of the Oklawal and St. Johns River basins.

The highly fossiliferous fresh water marl (limestone) and muck(organic materials) in the spring runs and river valleys are of great scientific interest. The lower calcareous marl contains the remains of many large extinct land vertebrates such as mammoth and mastodon These have been dated by the radiocarbon method as being 16,500 17,000 years old. There is a succession of superimposed marls with the youngest, more mucky material being younger than 4,000 years in age.

The algal gel in Mud Lake has received much attention from scientists interested in the origin of oil shale. The bloom of blue-green algae responsible for the watery collodial gel is the result of the lake having been highly eutrophic during most of the post-glacial time. Algal cell structures are still sharply defined at a depth of three feet within the gel. The lack of decay in this material, dated at 2280 + 200 years B.P is probably due to antibiotic factors. Some years ago H. K. Brooks obtained a core of the algal gel and underlying peat to a depth of 44 feet near the center of Mud Lake. A distinct unconformity occurs at a depth of about 14.5 feet below which muck, marl, an true fiberous peat occurs. A radiocarbon date of 8160 + 200 years B.P. (before present was obtained above the unconformity whereas the materials below the unconformity proved to be too old to date by this method, i.e., older than 35,000 years.

Under Lake George and, for that matter, throughout the St. Johns River basin there are thick deposits of fresh water sponge spicule clays. The genus Spongilla which stil thrives in the area contributed the predominant siliceous component. These lake deposi were used by the early Indians of Florida to make a distinctive type of porous, lightweight ceramic known as St. Johns Pottery. Spicules are minute needle or rod-like components made of calcium or silicon, which provide support to the skeleton-less sponges. The size and shape of spicules are used to identify sponges.

Structure

It has long been known that the top of the Ocala limestone is highly variable in t elevation it is encountered in wells drilled in eastern Marion County and in northern Lake County. No two structural contour maps give a corresponding interpretation becaus the structural pattern has not been completely understood. The relatively straight stretches of the Oklawaha River southeast of Sharpes Ferry, from Sharpes Ferry to south of Eureka and from Eureka northwestward are believed to be controlled by fault zones. The fault zones are a composite of small *en echelon* faults along which grabens and hors have been displaced. The relationship between the fault zones, individual tear faults and the horsts and grabens in the Ocala National Forest is shown in figure 60.

The three fault zones controlling the course of the Oklawaha River will be termed the Sharpes Ferry Fault Zone, the Eureka Fault Zone and the Mud Lake Fault Zone. From drilling and topographic evidence it is now recognized that a fault zone exists to the east of the high sand hills in the Forest. The trend of greatest vertical displacement is from Lake Dora to Lake Ker. This is named the Lake Ker Fault Zone.

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The two major subparallel fault zones, the Mud Lake and Lake Ker Zones trend in a N 16° W direction. They provide the eastern and western boundaries for the Mount Dora Ridge. The actual ridge is underlain by a graben complex in which the top of the Ocala Limestone has been displaced downward to over 300 feet below present sea level. Throughout the Ocala National Forest and Lake George region the top of the Ocala Limestone generally occurs between sea level and 20 feet above sea level, except for the downfaulted grabens.

The complex structures of the Oklawaha and St. Johns River valleys are all post Late Miocene in age. The Oklawaha River Graben is filled with very young materials of Pliocene or Early Pleistocene age. It is worthy of note that the two significant earthquakes reported in Florida, January 2, 1879, and October 31, 1900, were located in this area of north-eastern peninsular Florida.

Physiography

It is a common misconception that the landscape of peninsular Florida is all very young and that Early Pleistocene interglacial high stands of sea level inundated (flooded) the highest hills. Even the hypothesis that the last interglacial resulted in extensive flooding and that marine processes at this time modified the landscape to an elevation of 90 feet or so above present sea level is still commonly accepted by those not familar with recent scientific developments in interpreting the history of Florida.

The concept of the youthfullness of the Floridian landscape has prevailed despite the extensive terrestrial erosional features evident in the landscape of the Central Highlands of peninsular Florida as well as the large numbers of endemic species of plants and animals that have evolved in the habitats developed on the residual high sand hill ridges. For example, there are eight endemic (native) species of lizards and snakes unique to these habitats. The long leaf pine-turkey oak and the scrub pine forest are undoubtedly the most ancient continuously prevailing terrestrial environments in peninsular Florida. They date from Late Miocene time.

Geologists have been slow to recognize the antiquity of the landscape of portions of Florida because the glacial eustatic marine terrace theory was so convincingly developed y Cooke (1939). The catch is that glaciation began in the polar regions of the world efore the Pleistocene. We now know that glaciation probably began in Antarctica as early s Late Miocene time, 15,000,000 years ago, and that the highest stand of Pleistocene ea level relative to peninsular Florida was certainly not more than 100 feet above its present level. In relationship to this elevation, one must contrast the erosional landcape of much of the Central Highlands of Florida to that of the youthful terraced Coastal owlands. The Central Highlands is that area of peninsular Florida in which the land urface is predominantly 90 feet or more above present sea level. The present water table rairies, lakes and other karst features of Central Florida are all the result of reuvenation subsequent to a long Early Pleistocene period of karst planation to a water able in relation to the 90 foot stand of sea level.

Earlier in this book the birght colors of the "Citronelle Formation" were mentioned. hen the brown, orange and red portions of this formation are studied it is found that hey occur in the upper 20 to 30 feet of the materials below the land surface and the olorful zones are below and parallel to the topography. This zonation is a secondary eature and is the result of weathering and leaching. In other words, the residual and and hills associated with the high ridges of Florida are areas of paleosoils of which he surficial "Lakeland sand" is the residual A horizon (the upper layer of soil).

The great age of the Central Highlands of Florida is also proven by the deposits ssociated with the valleys of the Suwannee, Peace, Oklawaha and the St. Johns rivers. ate Middle Pliocene and younger river and estuary deposits are found in the river valleys roded subsequent to deposition of the "Citronelle Formation."

For biographic reasons the great age of the high sand hills of the Ocala National Forest has been established first. The next most significant feature of the Forest is the paleodune field. As was stated earlier these surficial wind blown deposits still retain the original topographic expression as transverse dunes developed by northeasterl winds. They are relic of intervals of greater aridity that exists today in the area. Most dunes in Florida are associated with present or past shorelines but the vast dune field of the Ocala National Forest is not. In many areas of the Forest the dunes are now partially or completely covered with water as the result of post-glacial rise of the water table. It is logical to conclude the aeolian (wind transported) features were developed because of aridity, lack of vegetation, and strong northeast winds at times during glacial stages and lower stands of sea level and the watertable.

The highest hill in the Ocala National Forest is about 180 feet above present sea level and Lake Goerge is only 0.8 feet above mean sea level. The relief features are for the most part the result of erosion. The pattern of erosion both by surface streams and subsurface limestone solution has been controlled by the structural relationships of the underlying materials. There is no question but that the course of the Oklawaha River has been determined by faulting and it is probable that uplift and solution has be the dominant influence in the development of the St. Johns River Offset. The position of the sand hill ridge occurs where a graben complex has been downfaulted. The most noteworthy feature about this ridge is the topographic reversal that has taken place. The down-faulted blocks are now the areas of highest relief within the Forest.

The beautiful sink hole lakes in the Forest are in the areas of relative uplift where the underlying limestone occurs at a shallow depth and has been subjected to great dissolving action by downward flow of infiltrating rain water. (Water and carbon dioxide create carbonic acid which dissolves limestone.) The karst lakes and prairies to the east and west of the sand hill ridge in the Forest have developed subsequent to a perio of planation at a level about 90 feet above present sea level.

Some of the most significant springs in North America occur in or near the Ocala National Forest. They issue directly from the Floridan aquifer. Silver Springs east of Ocala is the largest with a daily discharge of about 500 million gallons whereas Alexander Springs southwest of Astor has a flow of 76 million gallons per day. Salt Springs west of Lake George near Lake Kerr is the most distinctive, the water of which has nearly 6,000 parts per million of mineral matter. The water of this spring, with a temperature of 75° F, is issuing from considerable depth and is two degrees warmer than other springs in the area. Fern Hammock Springs and Juniper Springs are beautiful exotic springs. There are more than 20 small springs between Eureka and Rodman Dam on e Oklawaha River. The runs of all of the springs are among the most scenic features of Florida. The white fresh water snail shells that one sees so abundantly in the springs and spring runs have, for the most part, eroded from marl deposits representing a different former climate and hydrologic regimen.

The highly eutrophic nature of Mud Lake in the Forest appears to be due to dischar of sulphurous ground water high in nutritive content into the lake. White filimentous growths of sulphur bacteria can be observed at several places. A small boil at the boa launching site of the hunting club on the southeastern side of the lake has a mineral content of 308 ppm. This hard water lake is very unusual in that its water varies from 200 to 300 parts per million of dissolved mineral matter.

It is a shock to the uninitiated to see advertisements of live blue crabs for sale in the area of Lake George. It is a fact that the St. Johns River system is characterized by a marine fauna and flora. In addition to many marine fish, the fauna includes such salt water invertebrates as clams, polychaete worms, amphipods, isopods, shrimp an crabs. Though Lake George is only 0.8 foot above mean sea level, it is not subject to tidal influences. The salinity of the lake varies but is generally greater than 1,000 ppm. or 1 part per thousand (sea water is 34 parts per thousand). It is the discharge of large amounts of salty water into the St. Johns River that has made the post glacial

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invasion of marine organisms into the upper portions of the St. Johns possible. Blue Springs water has 1,660 ppm. or mineral salts, Ponce de Leon Springs has 1,256 ppm., Salt Springs has 5,210 ppm. and even Silver Glen Springs has 1,400 ppm.

When the landscape of the Ocala National Forest is considered in relationship to the origin of the relief features it can logically be divided into (1) the Oklawaha River Swamp, (2) the Oklawaha River Lowlands, (3) the Lynn Karst, (4) The Mount Dora Ridge, the Marion Uplands and the St. Johns River Offset Lowlands. These distinctive divisions are depicted in figure 63.

The Oklawaha River Swamp. - The low hardwood forested areas of the floodplain of the Oklawaha River also genetically includes the swamps associated with Mud Lake and Silver Run. These are areas that are seasonally flooded. Though depositional in origin it is unique in being the result of accumulation of calcareous marls and organic matter, not detrital mineral matter.

The Oklawaha River Lowlands. -- The extensive areas of wet flatwoods west of the Oklawaha River at Eureka and southward are generally less than 90 feet above present sea level and are directly underlain by sand and unconsolidated plastic clay. This distinctive area also extends southward from Sharpes Ferry in the graben-like structure.

Lynn Karst Terrain. -- Low sand hills and altered flatwoods occur throughout the western portion of the Ocala National Forest south of the Eureka Fault. The presence of many solution basins characterize this topographic entity. The Ocala Limestone occurs at a relatively shallow depth but in places it is blanketed by 100 or more feet of Miocene sediments. Away from the flatwoods associated with the Oklawaha River the area is mostly well drained hills on which the surficial sands are residual from the "Citronelle Formation." It is an area of great diversity in forest type but long leaf pine and turkey oak are the dominant trees.

Mount Dora Ridge. -- The portion of the Forest above 100 feet elevation consists of a NNW-SSE trending ridge which is interrupted to the east of Eureka. This ridge consists of residual hills of "Citronelle Formation" upon which a paleosoil developed prior to deposition of surficial aeolian sand. Scrub pine and long leaf pine-turkey oak occur through this topographic division. There are no lakes.

Marion Uplands. -- Though termed an upland, no portion of this division is above 90 feet; generally the elevation is 50 to 75 feet. There are scattered karst lakes and prairies. Many lakes are small and clustered. It is probable that migrating dune sand during a lower stand of the water table has caused this complexity as at Farles Prairie. The spring runs and lakes in the region are below 25 feet above sea level. Except for two large sand hills and the Cirtonelle outcrops in the vicinity of Lake Kerr and northward, this area is uniformly forested by scrub pine.

St. Johns River Offset. -- The Marion Upland abuts Lake George on its western shore from Salt Springs Run to Silver Glen Springs Run. The lowland to the north and south of these runs is underlain by a diversity of materials. Some are Middle and Late Pleistocene estuarine deposits; there are drowned dunes in the area of Astor and southward, and the low swamps are generally underlain by near-Recent mucks and marls. The land is generally less than 25 feet above sea level and is poorly drained. It is forested predominantly by pine flatwoods and hardwood river swamp associations.

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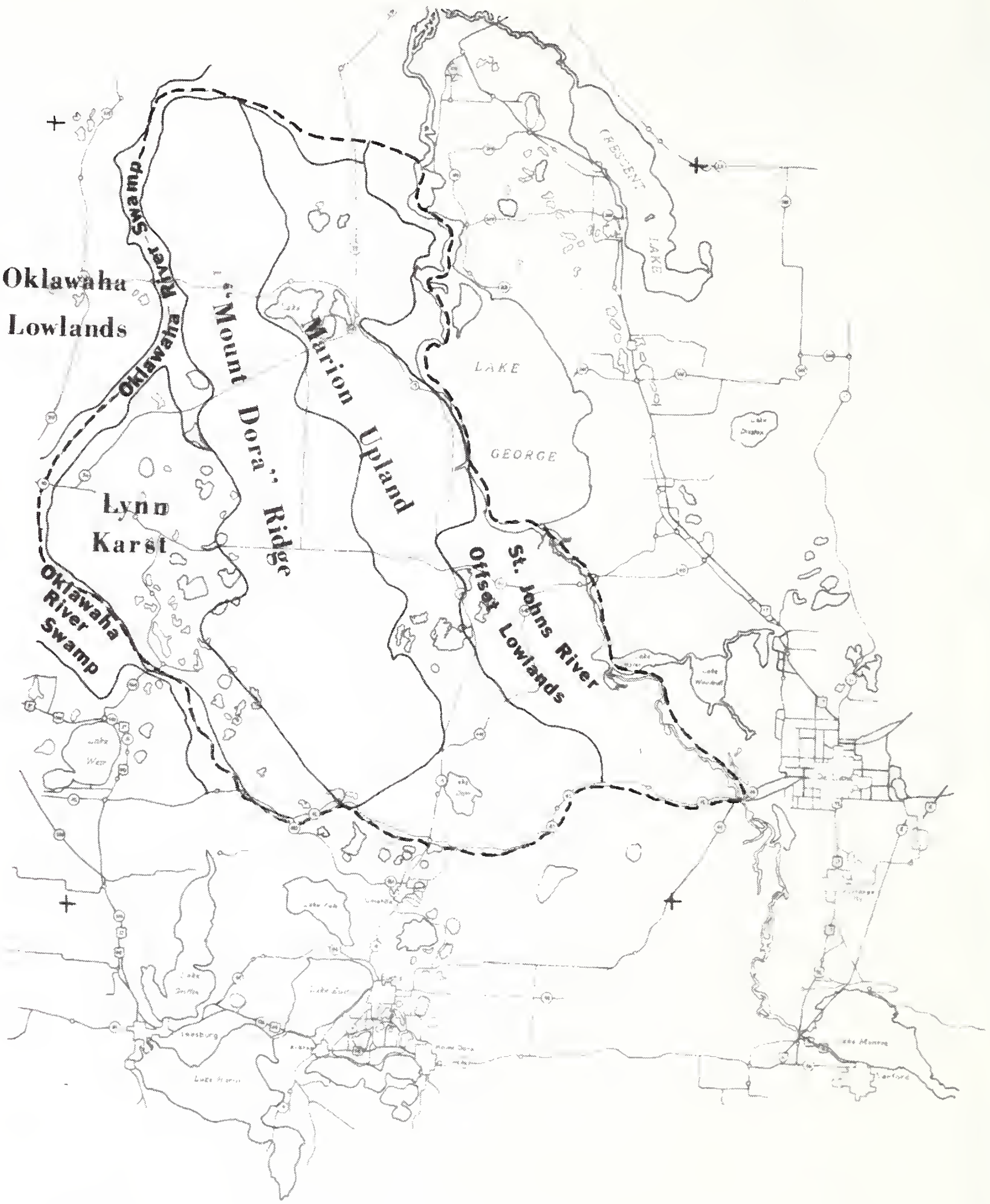

Figure 63. - Physiographic divisions of the Ocala National Forest.

CHAPTER V

CLIMATOLOGY

The dynamic aspect of climate is one of the major determinants of the structure and function of ecological systems and the landscape in general. The discussion on the geology of the Ocala National Forest has described some of the long-term physical results of the effects of climate on the landscape. The natural features of the Ocala National Forest evident today are the transitory results of this long-term process as modified or augmented by present day conditions. Except in particularly obvious examples, we seldom are aware of the degree to which climate also helps to mold not only the structure but also the function of the biological units of the landscape. This chapter serves to summarize how climate is related to both the modification and maintenance of ecosystem structure, and particularly, function. The reader is referred back to both Chapters II and IV for related background material.

Earlier in this century, the awareness of the importance of climate was manifested in a theory of succession which proposed that sequences of succession all culminated in a region-wide climax vegetation type known as the climatic climax. The progression to a climatic climax, its composition and function were believed to be controlled by climate. Of course, other environmental factors such as soils, topography and geology also have important roles in modifying ecosystem structure and function. Thus, the importance of climate as an environmental determinant is well recognized.

Climate may be defined as the aggregate of all atmospheric or meterological influences which collectively characterize a region. These influences include moisture, temperature (as a measure of heat), wind, pressure and evaporation. All of these climatic factors are nterrelated to one another and the energies necessary to power these functions are ultimately derived from the sun. The transfer of solar energy to the earth's atmosphere and terrestrial surface and its loss back to space was broadly described in Chapter II (pp.12). Additional detail will now be presented to provide the framework for interpreting the climatological nfluences on ecological systems. The reader is referred to figure 65 for a classical view of rainfall and temperature for one station within the Ocala National Forest and one station to the north and to the south.

Rather than take the traditional approach to describing climate and climatic functions (this is thoroughly covered in many good texts, see reference section), we will illustrate the interactions of climate and a generalized ecosystem of the Ocala National Forest. This llustration (figure 64) will also assist further in learning how to read energy network diagrams. For convenience, each symbol is designated by a letter and each flow by a number. They are described in sequence:

As stated previously, the sun (A) is the source of all contemporary energy and is shown in the diagram to be powering (1) photosynthesis. It is also shown, by means of a dotted line (2), to be contributing to atmospheric heat (B) which in turn maintains (3) the global atmospheric pressure system (C). Differences in atmospheric high and low pressure zones create wind (D) and is illustrated as an interaction (4) between the two. The dynamic (changing) atmospheric pressure systems are also responsible for maintaining the patterns of rainfall (E) and dry air (F) over pathway (5). In reality, each of these seemingly isolated interactions occur simultaneously in the same atmospheric volume and thus are indicated by dotted lines. They are separated out, however, as each represents an energy source relative to some process(s) in the ecosystem of interest.

The potential energy in solar radiation incident (1) on the ecosystem is shown entering the producer component (G) in which several subcomponents are detailed. The amount of solar

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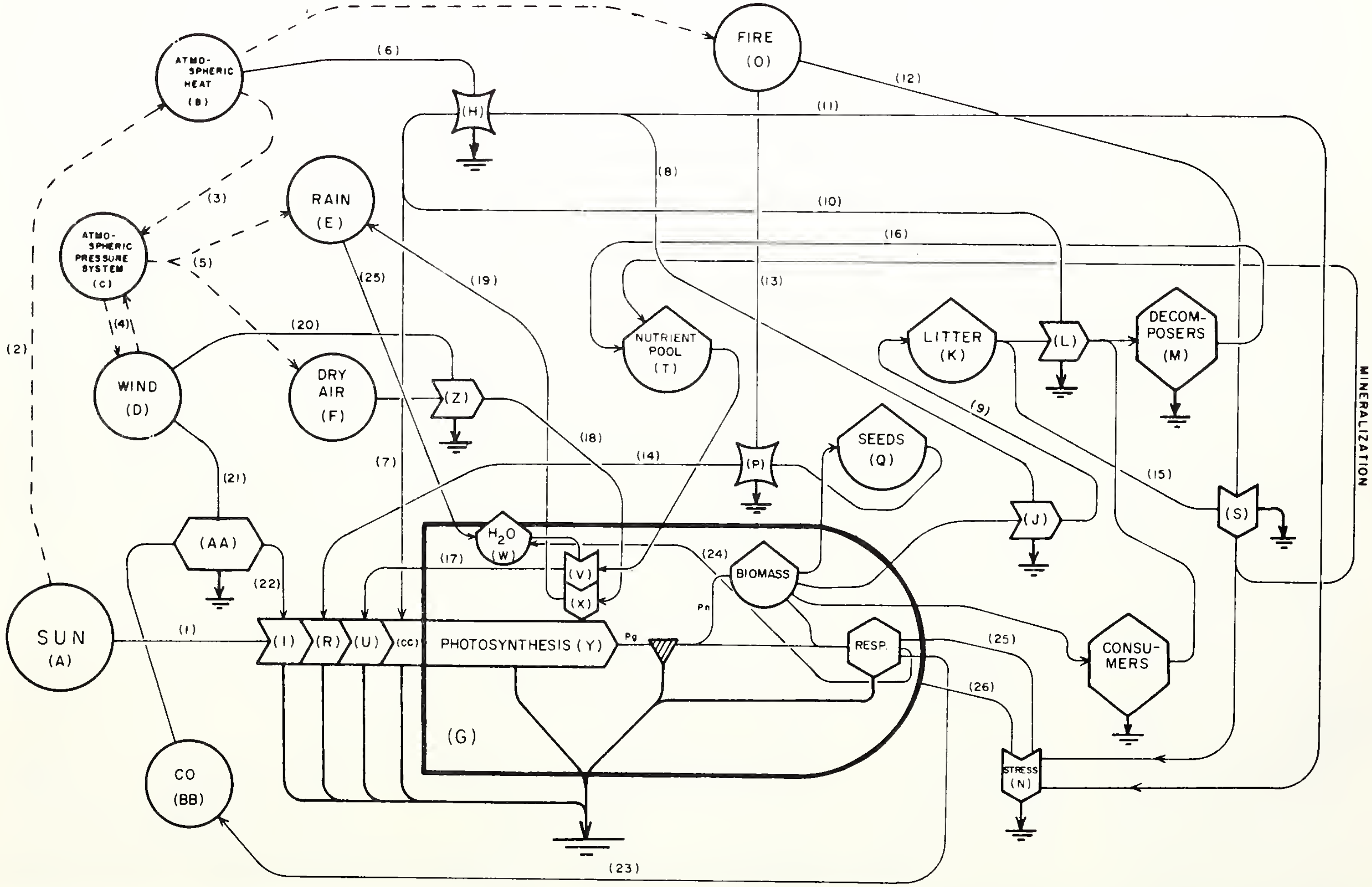

Figure 64.-An energy diagram model of the interaction of climate and a generalized ecosystem.

ergy which may be converted to chemical energy (potential), and thus available for further
e, is proportional to the influence exerted by numerous forces. In the diagram, heat, i.e.,
mperature) is shown operating (6) as a switch on the flows (7, 8, 10 and 11). These in
rn, operate several amplifiers, or workgates. The ON-OFF switch is ON when there is
fficient heat to maintain optimal growth temperatures. This flow (7) is shown operating
plifier (CC). When the switch if OFF, i.e., too cold, flow (7) controlling photosynthesis
ops and flows (8) controlling litter fall and stress (11) become operative. Flow (8)
erates multiplier (J) which stimulates leaf fall during the winter. The leaf fall con-
ibutes (9) to the forest floor litter storage (K). Of course, decomposer (M) activity
negligible during the winter and the amount of litter (K) increases. However, just as
timally warm temperatures promote growth, so do decomposers respond to increasing tempera-
re. Thus, when it is warm a portion (10) of the ON flow stimulates the decomposers (M)
d the litter storage in (K) is reduced. Cold weather is also a stress on the system in
at compensatory energy is drained away. This is shown as flow (11) operating the stress
plifier (N).

A second major stress on the system is fire (O) which also diverts energy from the
stem in proportion to the frequency and intensity (12) of fire. It should be noted, how-
er, that fire is a stress on the system only in the short term view; the overall long term
fect benefits the system by permitting its survival. This is illustrated by the switching
fect (13) on the germination (P), for example, of sand pine seed (Q). If there is no fire,
ere is no germination. Of course, without fire and thus failure of germination, regenera-
on ceases and the sand pine ecosystem goes into decline. Thus, the energy (14) of regenera-
on has am emplifying (R) effect on the overall system. Note that the frequency and inten-
ty of fire, among other factors, depends upon an abundance of dry organic fuel (in K).
re burns in proportion to the amount of fuel available, indicated by flow (15) and symbol
). Another benefit of fire is the rapid mineralization which occurs when fire turns organic
terials into ash. The mineral element constituents are thus "released" and available for
take by the regeneration (new) vegetation. The fire stress on the system contributes to
e nutrient pool (T) whose major output flow is shown re-entering the producer component (G).

The nutrient pool (T) is seasonally maintained by the products (16) of decomposition
) in addition to the irregular pulse of fire. The availability of these nutrients, as a
nction of uptake (flow 17 and workgate U), is dependent upon evapotranspiration (V).
e ability of plants to absorb water from the soil and release it back to the atmosphere
dependent upon the drying power of the air (F) and, obviously, the availability of water
). The movement of water through plants assists in the uptake and translocation of these
quired nutrients. The water storage capacity (W) of the ecosystem is maintained by rain-
ll (E) entering along pathway (25). Dry air (F) powers (18) workgate (X) and the result
that the water (W) is pulled through the plants and with it nutrients from the soil
orage pool. The water then returns (19) to the atmosphere and the nutrient flow (17)
ives photosynthesis through amplifier (U). Water, of course, is used in photosynthesis
) and the amounts of nutrients, water and dry air are critical. Thus, the wind is
llustrated as a force (20) pumping (Z) dry air into the system (G). Similarly, wind (D)
erates (21) a two-way workgate (AA) pumping the carbon dioxide (BB) to operate (22)
rkgate (I). Carbon dioxide is replenished (23) through respiration which also yields
4) water.

To complete the diagram, the products of gross photosynthesis (Pg) are shown contri-
ting to a storage of biomass and being used in respiration (RESP). During stress condi-
ons, some of these energies are lost through accelerated respiration (25); a portion of
e overall stress (25 + 26). Flow (26) represents structural losses to stress. For
ample, storm damage or loss of a species. The pathway Pn is the net production which
cumulates as biomass; potential energy stored in structure, a portion of which is avail-
le to do various kinds of useful work in the system.

In this discussion, the broad overview of climatology and ecosystem interactions
ggests that, as a subject, both must be considered together. Climatology is a well-defined

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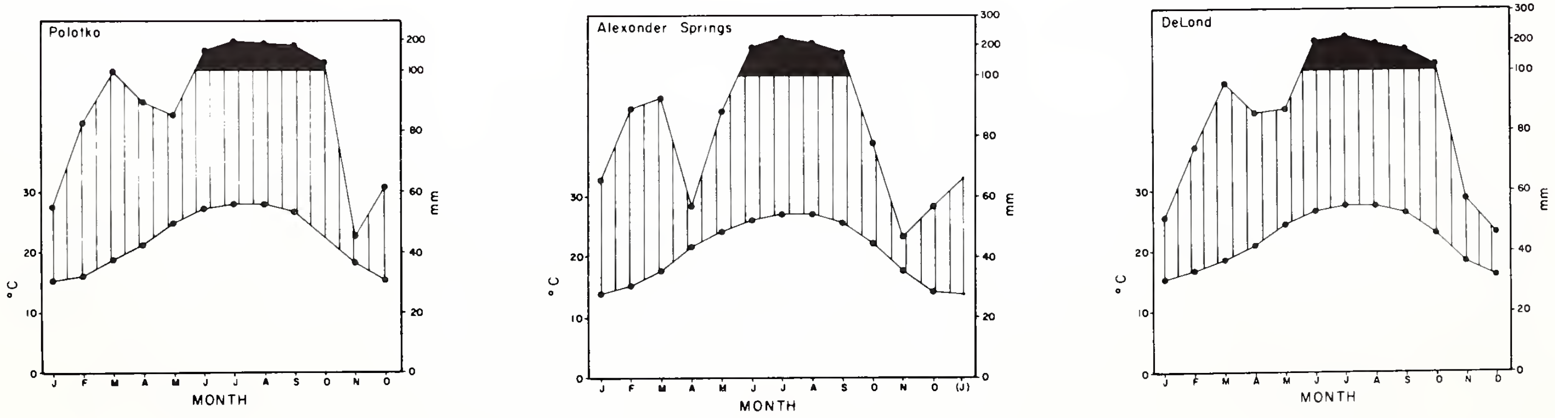

Figure 65.-Climate diagrams for Palatka, Alexander Springs and Deland based on the concept of Walter and Lieth (1960). The left-hand scale is in degrees Centigrade and corresponds to the bottom curve of mean monthly temperatures. The upper curve is the mean monthly rainfall in millimeters on the right-hand scale. The shaded portion of each diagram represents the period during the year in which the mean monthly rainfall exceeds 100 mm per month and the vertical lines above the temperature curve represent the period when rainfall exceeds evaporation. To convert Centigrade to Fahrenheit, multiply °C times 1.8 and add 32, e.g., (20°C x 1.8 + 32 = 68° F). To convert millimeters to inches, multiply 0.039, e.g., (100 mm x 0.039 = 3.9 in.).

ience and appreciated by many, but traditional views (see figure 65) often tell us little out the aspects of real interest. In Chapter VIII, additional detail is presented on rtain climatological factors as they relate specifically to the ecosystem of the Ocala tional Forest.

e Climate of the Ocala National Forest

The climate of the Ocala National Forest may be characterized from the climate diagrams igure 65) prepared for Palatka, Alexander Springs and Deland. Palatka and Deland are, spectively, to the north and the south of the forest and all three are aligned along e eastern forest boundary. However, the coverage and range are sufficient to describe e regional climate.

The climate diagrams show that the region experiences a rainy season of three to four nths during the summer. This is the period during the year when rainfall exceeds 100 mm .94 in.) per month. The total annual rainfall is in excess of 1300 mm (over 50 in.). e driest months are November and December which describe the winter dry season. April d May are the next two driest months and April is particularly dry in the Alexander area. e monthly rainfall, however, is never so low as to define a true dry season characteristic some other areas in the world.

The temperature curves of the region are characteristic of mild climates without vio- nt diurnal (daily) or seasonal (yearly) extremes. Such extremes are common in deserts ery hot days and very cold nights) and in the northern United States (very hot summers d very cold winters). Although the climate is mild (21° C or 70° F), daytime summer mperatures occasionally rise to over 40° C (104° F) and frost, with temperatures below eezing, is common during the winter. During the year there are over 100 days during which e temperature rises to over 32° C (90° F). The daily temperature fluctuation is not parent in the climate diagrams which only show monthly means.

The forest visitor to the areas of sand pine or longleaf pine-turkey oak is usually pressed with its "dry" appearance. The problem may be perplexing when one considers at the rainfall is fairly well distributed over the forest as indicated in figure 65. y, with a uniform rainfall pattern do some areas appear so dry and others so moist? The swer lies in the permeability and drainage of the soils. The sand pine and sandhill mmunities are found on elevated areas of deep well drained sands. Rainwater in these eas drains quickly into the soil and into areas of lower topography. Thus, the total ailable water in these communities is very low during the periods between rains and the eas appear dry. This illustrates an important concept; descriptions of single climatic ctors (e.g., temperature, rainfall) tell us less about an ecosystem than descriptions of w these factors interact with one another and the physical-biological environment.

A close examination of the climate diagrams (figure 65) shows considerable variation the absolute rainfall and temperature during a year. In consideration of ecosystem nction, it is probably more significant to note the periodicity in the timing of the et" and "dry" months. The periods between wet and dry, and dry and wet, are the periods greatest environmental change. Thus, one might also expect dramatic changes in ecosystem nction(s) coincident with these periods. Such reciporcal responses to rapid climatic anges describe the phenology of an ecosystem. That is, when during the year certain nctions become dominant, such as leaf fall, flowering, fruiting, leaf initiation, etc. own in figure 66 is one view of the phenological pattern in a mixed hardwood forest in ich the timing of peak litter fall is related to the time of the year. Compare this gure with the seasonal climate patterns in figure 65. Can you determine the season observing the worn-out ecosystem parts lying on the forest floor?

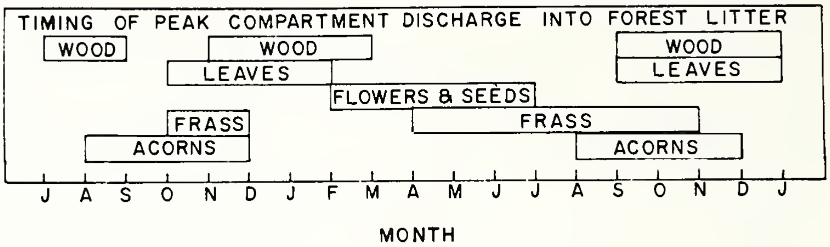

Figure 66.-The phenology of a mixed hardwood forest as reflected in the timing of peak discharge of components into the forest litter. Note how each is related to a particular time of the year. Differences in the onset, duration and cessation of discharge describes seasonal climatic variations. For instance, winter may start early one year or the wet season may be unusually short; ecosystems respond accordingly. Frass is a polite word for insect feces and compartment is used to describe a specific functional component of an ecosystem, e.g., wood compartment or leaf compartment.(from Lugo, Snedaker and Gamble, 1972.)

CHAPTER VI

THE COMMUNITIES OF THE OCALA NATIONAL FOREST

Introduction

The communities of the Ocala National Forest are recognized and described on the basis of the dominant plant species occupying an area of interest. Although communities could also be defined and delineated on the basis of the animal occupants of an area, it is the plant species that are the most obvious. This chapter will present a cursory description of the Ocala National Forest's major communities based on the characteristics of the typical vegetation and certain aspects of the environment. Notes of interest concerning the dominant plant and animal species provide an insight into the diversity of these communities. The comment on each species follows its first listing under community components and where it is described implies no particular importance in that community. A complete checklist of animal species appears as an appendix. The following chapter (VII) describes in some detail the basic interaction forms between species which together with this Chapter provides a foundation for interpreting the ecology of the Ocala National Forest.

Plant Communities and Soils

The diversity of communities commonly observed within the Ocala National Forest is strongly associated with the diversity of soils as shown in Table 7. The expression of the soils-community relationship is less associated with the inorganic characteristics and fertility of the soil than with its role in maintaining suitable moisture characteristics. In this regard, however, the water balance is also a function of soil texture and depth to the water table, the latter itself a function of elevation and topography (see Chapter IV for the geological basis). Because rainfall is essentially uniform over the Ocala National Forest, but unevenly distributed during the seasons of the year (see Figure 65), the abundance of water is the strongest controlling factor influencing the distribution of plant species and their assemblages into plant communities. The chapter on geology emphasized the dominant silicious sands and carbonate substrates in the Ocala National Forest, both of which have poor water holding capabilities when present above the water table.

The overwhelming majority of the upland soils are low in organic matter with an xcessively to well-drained sandy surface layer over 40 inches in thickness. They are or the most part strongly acid and very low in fertility. Depth to the water table is sually in excess of 60 inches. The most extensive vegetation types (xerophytic and esophytic hardwoods, sand pine scrub and longleaf pine -- turkey oak sandhills) occur n these soils and exhibit functional adaptations to fires resulting from the fire freqency during the recurring, severe dry seasons. The severity is due not so much to the ack of precipitation as it is to the rapid loss downward through the loose, permeable ands. The mesophytic hardwoods, however, because of a more favorable moisture balance, re seldom destroyed by fire, and thus, are considered a more evident product of succession. The more luxuriant mesophytic hardwood forests are able to exist on these deep ands primarily because the soil-moisture holding properties (and fertility) have improved ith time and the continued incorporation of organic material.

The flatwoods vegetation type occurs in low level areas with sandy, strongly-acid soils and a relatively high water table. A dominant feature of these soils is the presence of an organic-stained pan at two to six feet below the surface resulting from the igh, fluctuating water table. These soils become inundated during periods of prolonged rainfall as rapid runoff is precluded by the flat, level topography. The generally favorable water balance and the periods of inundation restrict the dominant vegetation species of four pines, arranged in order to increasing moisture tolerance: longleaf, Table 7.-The correlation of soils and vegetation. This relationship between the soils and communities of the Ocala National Forest is based on the amount and seasonal availability of water. The sands drain very quickly and become very dry during periods of no rain. Other soils do not drain easily or are flooded during some portion of the year. The soil series names distinguish soils of differing but recognizable properties such as texture and fertility.

INCREASING MOISTURE →

DRY MOIST WET

SOIL SERIES	Sand pine Scrub	Xerophytic Hardwoods	Sandhills	Mesophytic Hardwoods	Flatwoods	Hydrophytic Hardwoods	Marshes & Prairies	Aquatic Communities
Lakewood	X							
St. Lucie	X	X						
Pomello	X	X		X				
Paola-dry	X	X						
Paola-Moist	X			X				
Lakeland			X					
Astatula, dark surface			X					
Norfolk			X					
Blanton			X	X				
Astatula, lamellae substratum			X					
Orlando			X					
Taveres					X			
Mascotte					X			
Pompano					X			
Bladen					X			
Coxville					X			
Osier					X	X		
Bayboro					X	X		
Oviedo					X	X		
St. Johns					X	X		
Sellers					X	X		
Leon					X		X	
Immokalee					X		X	
Basinger							X	
Myakka							X	
Everglades								X
Dorovan								X

slash, loblolly and pond. The pan is a relatively impermeable layer of materials which have leached from the soil above it and accumulated at the level of the mean water table. Tree roots seldom penetrate the hard pan and the effect is particularly noticeable in the flatwoods; the closer the pan is to the surface, the shorter the trees.

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The other major vegetation types, hydrophytic hardwoods, marshes and prairies, and quatic communities, are adapted to low wet areas which may be inundated during a greater ortion of the year. Heavy clays and organic soils (peats and mucks) are common in these reas and may occur together in layers. The hydrophytic hardwoods occur along rivers, reeks, streams and in the swamps and are best exampled along the Oklawaha River portion ot affected by the abandoned barge canal. The marshes occur in low areas interspersed mong the other vegetation types. Both the hydrophytic hardwoods and marshes may be found n peats and mucks from two to ten feet in thickness. Occasionally the organic soils may e interlaced with both layers of clay and marl. Marshes, not maintained by an existing ody of water, may result from a high water table or drainage into and retention of water y a subsurface clay lens in low areas. The prairies, however, occur in low sandy soils ver a highly fluctuating water table. Usually found adjacent to marshes and lakes, they requently go dry during prolonged dry periods. Aquatic vegetation, devoid of trees, ccurs as submerged and emergent communities in all shallow waters. The soil substrate, erpetually submerged, is made up of marls, clays and organic soils, usually in alternating ayers. The introduction of exotic species, such as the water hyacinth, is altering the haracteristics of many of these Florida communities.

erophytic Communities:Scrubs and Sandhills

Of all the ecosystems of the Ocala National Forest, probably none are subjected to reater environmental stresses than the sandhills and scrub. Although their existence ears witness to their evolutionary success, it may only be deduced from their structure nd function as to what unique adaptations have enabled this accomplishment. Unlike the ydric ecosystems, where the adaptations to periodic inundation have engendered an obvious ependency on this "stress" equatable adaptations are somewhat more obscure in the xeric dry) ecosystems. It has already been stated that existing systems are more or less dapted to the prevailing and average environmental conditions, irrespective of whether an considers them, from his viewpoint, to be "beneficial" or "detrimental." Thus, it is nly the unusual or unique factor within that environment that can be labelled a contemporary tress. Thus, once again stated we may now take liberties with our language and discuss eric adaptations to stress as expressed in these two communities.

To a temperate-adapted human, the xerophytic sandhills and scrub are hot, dry and a ecidedly uninviting place to establish one's home. Thus, one might state with suitable ccuracy that heat is the most universal stress in these areas. Indeed this is true. ne relative hotness or coolness of a regional ecosystem is to a large extent dependent on ne amount of free water available for evaporation. Evaporating water requires at least 40 calories per gram to go from the liquid to the gaseous state; the heat loss due to ne evaporation process cools the heat-donating material, be it air, water, soil or some ther component. Thus a terrestrial ecosystem with more available water tends to be cooler nan one with less. Although all Ocala National Forest ecosystems receive relatively the ame amounts of precipitation and insolation, the loose deep sands of the xeric systems ermit rapid downward loss. These environments, with a low amount of free water available or evaporation, are thus noticeably hotter. The more conspicuous adaptations to xeric tress are, in fact, mechanisms to conserve scarce water rather than adaptations for protection against the heat. Observe, for instance, the number of sclerophyllus (dry, leathery) eaves, succulent plants (cacti and euphorbs) and the sparseness of ground cover.

One of the conspicuous features of the sandhills and scrub communities are the numerous nd varied mounds of sand. They may be observed in all sizes, with or without apparent urrows, but are for the most part uniformly of darker yellows or oranges than the soil pon which they are lain. These are creations of such organisms as ants, beetles, tortoises, ocket gophers, and mice. They are utilized by the builder or by other creatures seeking omentary refuge or a permanent shelter. Rattlesnakes are common opportunists within the arger burrows and occasionally a skink may be observed almost completely buried in the oose sands of the mounds. Whereas it is not suggested that one attempt to extract rattlesnakes from such burrows, collectors have devised a simple technique for bringing the snak out. All the collector needs is a length of flexible hose to wiggle down into the burrow and a noxious fluid such as gasoline or auto fumes to introduce into the hose. Obviously, the occupant will waste no time in making his exit.

The burrowing activities of these organisms have effects on the ecosystem beyond just providing sanctuaries for the host or his guests. The highly permeable, deep sands of the xeric ecosystems are subject to rapid downward leaching of nutrients during rainy periods, despite a suggested efficiency of mycorrhizal systems. The deep burrowing activities brin soil to the surface producing an effect similar to deep plowing. Although, the magnitude of the soil turnover does not appear great in one location, the total, over a period of years, must be quite large. The darker color of the retrieved soils attest to its origina depth; oxidation (literally, rusting) of iron becomes increasingly more apparent with dept Iron is a required element in the nutrition of both plants and animals and occurs within them in a reduced form. In litter and detritus the reduced iron is freed by decomposition and leaches downward through the soil where it goes from a reduced state to an oxidized state. Whereas oxidized iron (rusted) accumulates in the soil, the burrowing organisms bring it back to the surface for reuptake and reduction by plants. The burrowing organism of the xerophytic ecosystem thus function as workgates in the flow of energy, in addition to their more obvious roles as direct agents in trophic transfer.

The Scrub

The scrub is a plant community restricted to the State of Florida. The world's large continuous sand pine community occurs within the Ocala National Forest and covers an area some 35 miles long by 15 miles wide along a north-south axis. The name, sand pine scrub, results from its occurrence on well-drained sandy soils and the dominance of sand pine, which has a scrub appearance in comparison to longleaf pine.

The scrub occurs on the well-drained sandy soils of the Lakewood, St. Lucie, Pomello and Paola series on relic shore dunes rising to some 180 feet above mean sea level. These sandy dune deposits were created landward from the geologic shorelines of the Pleistocene and Recent eras. The lowest relic shoreline occurs at about 25 feet elevation on the east periphery of the scrub. The dune sands, washed and sorted by marine currents and wave action, are well drained and leached of soluble salts. Together with the rapid oxidation through decomposition of organic detritus, these silicaceous sands are considered relativ infertile.

In addition to the sand pine, there are many species of evergreen shrubs (about 70% of the total number of woody species) but very little herbaceous ground cover. The lack of abundance of this flammable cover of grasses and herbs may result from overall ability of the community to utilize nutrient and moisture resources within its shrub and tree components to the competitive exclusion of these lower forms. Coupled with its evergreen nature, there is no seasonal leaf drop contributing to a rapid build up of forest fuels prior to the winter dry season. Thus, ground fires are a rare occurrence. Fire does occur as a result of lightning and man, and in these instances it is a crown of fire which completely devastates the forest. A crown fire burns through the tops of the trees and is much hotter than ground fires which burn the litter and understory vegetation beneath the crown. Sand pine crown fires burn almost explosively due to the "varnish" which coats the needles. This coating, produced by the buds, is a highly flammable material. Because of the homogeneous nature of this community, such fires are capable of burning large areas in a very short period of time; 35,000 acres were burned in four hours in 1935. Whereas, the crown fires are highly destructive, the survival of the scrub community is dependent upon a continuing sequence of destruction and renewal. The fire removes the existing structure and the heat of the fire causes the cones of the sand pine to open and release their seed in the open areas of ash and bare mineral soil. Without heat, sand pine seed does not

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erminate and without fire stimulated regeneration of sand pine stands these forests would egin to decline from heart rot at about 50-55 years of age. Such areas may be observed round the fringes of the scrub. Contrary to its appearance, the other community components re not seriously affected as they also are regenerated by fire. The shrubs regenerate uickly from root sprouts, and pioneer species, capable of rapid invasion, all contribute o creating a mantle of greenery over the burned area within a year or two.

The sequence of destruction by fire followed by the regeneration of the community, ontributes to the variations in the regional appearance of the forest. The simultaneous ermination of sand pine gives rise to an even-age, relatively homogeneous stand such as s schematically diagrammed in figure 67. This characteristic of the sand pine lends itelf to management by the Forest Service for the production of pulpwood on a sustainedield basis. Sand pine stands which enter into decline due to senescence (old age) take n an appearance similar to that which has been stylized in figure 68. Given sufficient ime without further regenerative disturbance, the community would evolve through succesion into a xerophytic hammock dominated by live oaks. The best examples of succession ulminating in a hammock are evident at the western edge of the scrub along the Oklawaha. iver Basin. Here the scrub is better protected from fire due to the presence of the ower elevation mesophytic and hydrophytic forests. It has been suggested that succession oward the hammock stage occurs more rapidly on finer textured sands than on coarser extures due to the better moisture holding properties which create more mesic conditions. n either situation, without fire, succession to the climax steady-state takes several undred years.

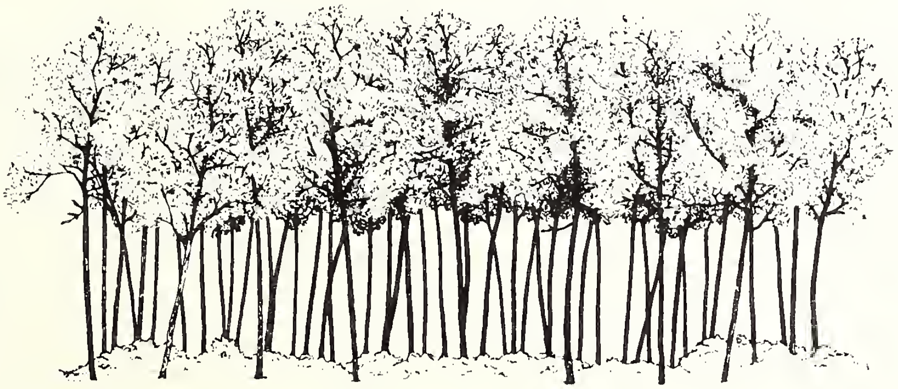

Figure 67.-A schematic profile of a sand pine forest. A sand pine forest is characteristically even-aged, closed canopy and contains individuals of relatively uniform size and spacing. Survivorship of individuals is described by curve A in figure 23; the majority of the population lives to maturity at which time there is a rapid increase in mortality.

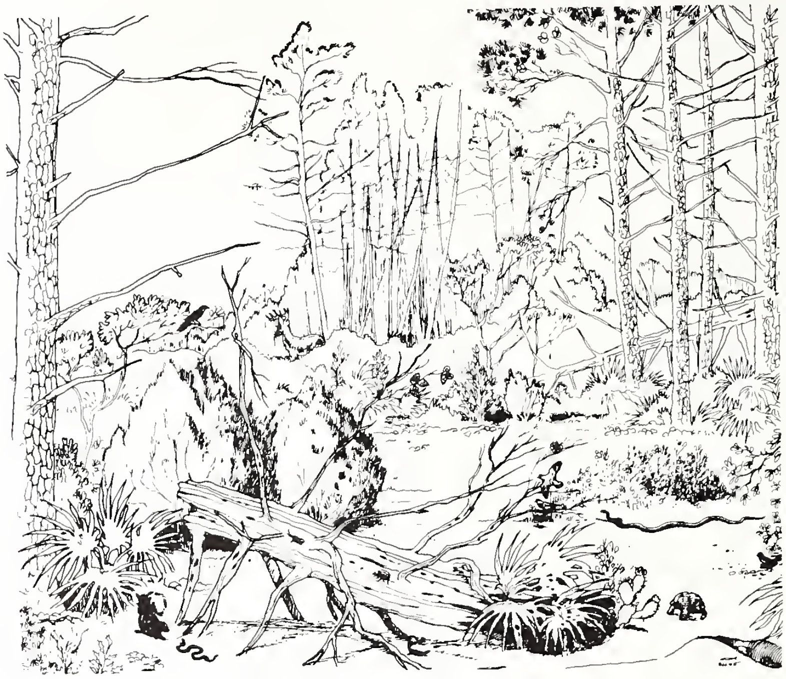

Figure 68.-A senescent (old, over-mature) sand pine forest. At maturity, the population begins to die off from heart rot and breakage. Since regeneration of sand pine does not occur without fire, the community composition shifts to shrubby hardwoods and will eventually develop into a (xerophytic) hammock. The species composition of this more mature stage has a higher species diversity as discussed in Chapter II (see figure 27).

The introduction of man as an ecosystem manager of the sand pine community seems to offer the guaranteed survival of this system. His techniques capitalize on the natural adaptations of sand pine, but reduce the vagaries of fire occurring at the wrong time or place, or the chance of a controlled management burn escaping to adjacent areas. This is achieved by protecting the entire forest from fire and by using rapid-response suppressio techniques on wild fires before they can move into the sand pine canopy. This policy, however, would not permit sand pine to regenerate naturally. To counteract this, sand pine seed are collected and artifically heat treated to ensure germination. Then they are distributed over cut-over area to re-establish the community. Prior to seeding, the area is site-prepared with a drum chopper.

Scattered within the sand pine community are small to large inclusions of longleaf pine and mesophytic hardwoods, locally called islands. Two of the better known are Pat's Island and Hughe's Island, focal points of the early settlers and the site of the movie, The Yearling. The moist soils in the islands, unlike the scrub soils, were more favorabl for agriculture. The islands are not the successional hammocks of the sand pine but rather represent islands of a different type of vegetation within a sea of sand pine. Th small swamp inclusions in the sand pine scrub also contain the world's largest known lobl bay.

The Components of the Scrub

To most casual observers, the sand pine scrub in all of its variant expressions is a spartan and rigorous community and therefore a community which contains few species. That the scrub is alive with so many organisms surprises all except those who have taken the time to momentarily become a part of the scrub. Figures 69 and 70 illustrate a few of the many species which one may observe within the scrub through careful and quiet observation. These figures are only suggestive as one would never expect to see so many organisms all active at the same time within so small an area. However, they are there and it is up to the visitor to use his powers of observation to find them.

Two scrub variants are used as the habitat background for portraying these representative species. Figure 69 is an enlargement of figure 68 which shows an area of a sand pine forest which has been allowed to become over mature. The fate of sand pine in this condition has been described. In figure 70, another variant of the scrub is illustrated. To some extent, this situation is similar to the successional areas which are recovering from a forest fire or a clear-cut harvest of sand pine. The format for presenting and describing the various species of the communities will be the same. The major communities will be depicted in a habitat scene along with a legend to the species illustrated. Both representative plants and animals will be listed and some of their more interesting aspects will be discussed.

Plant species of the scrub:

Pinus clausa - sand pine or scrub pine. Sand pine is readily distinguished from all other pines by its crooked trunk (oldest trees) and the fact that its needles occur in bundles of two and are about 3" long. The only exception is the spruce pine whose needles also occur in bundles of two about 3" long. The spruce pine, however, occurs predominantly as a component of the mesophytic hammock. Note that the cones of the sand pine are closed and that some are embedded within living branches. The cones will not release viable seed unless exposed to heat. One will observe that spruce pine cones are invariably open. The trees are harvested for pulpwood as the size is too small for quality lumber.

Quercus myrtifolia - myrtle oak. The myrtle oak is a common component of the scrub throughout Florida in areas similar in appearance to figure 70. Occasionally myrtle oaks will be so thick and well developed that they form an impenetrable thicket. Unlike the majority of the oaks encountered in the Ocala National Forest, the acorn meat of the myrtle oak, sand myrtle, and the bluejack oak is bitter to the taste and therefore is not a good wildlife food.

Quercus chapmanii - Chapman oak. This oak is named for one of the early field botanists in Florida and is one of the more common oaks in the scrub where it seldom attains a height of more than 25 feet. All of the scrub oaks are small in size when compared with the oaks of other communities. It is common on very well-drained soils. The famous inventor, Thomas A. Edison, once tried to make rubber from the milky sap.

Quercus virginiana var. *maritima* - scrub live oak or sand live oak. The scrub live oak is a dwarfed variety of the true live oak. The leaves of both are similar in that when turned upside down they look like a small canoe. The variety name of this oak means on or near the ocean and results from the presence of this species on coastal sand dunes. This suggests a prehistoric relationship with the Pleistocene sand dunes of the scrub area (see figures 59 and 62). The scrub live oak may be distinguished from the live oak by its size and shape and by the fact that live oak acorns are always paired.

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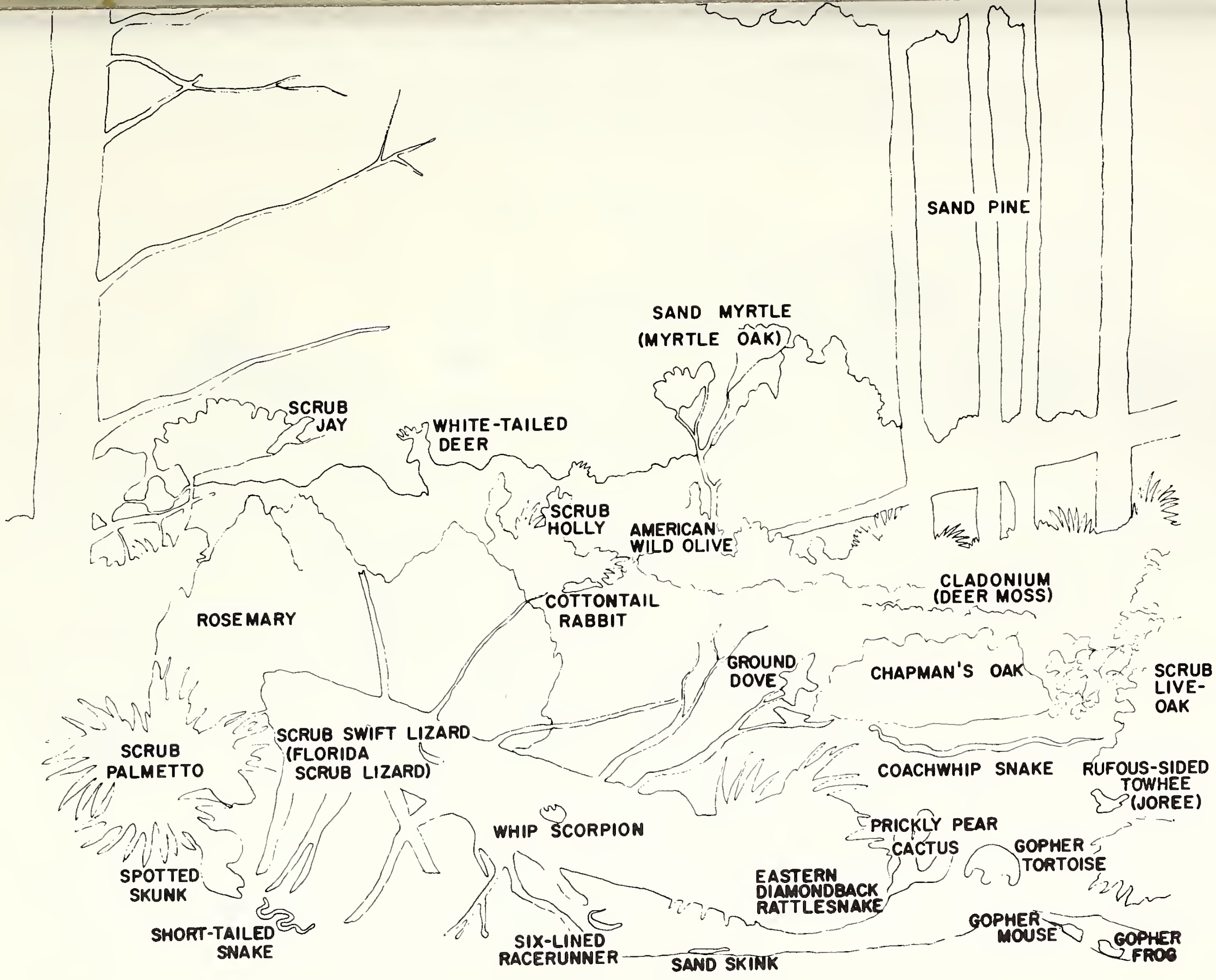

Figure 69b.-Location code for the species in figure 69a.

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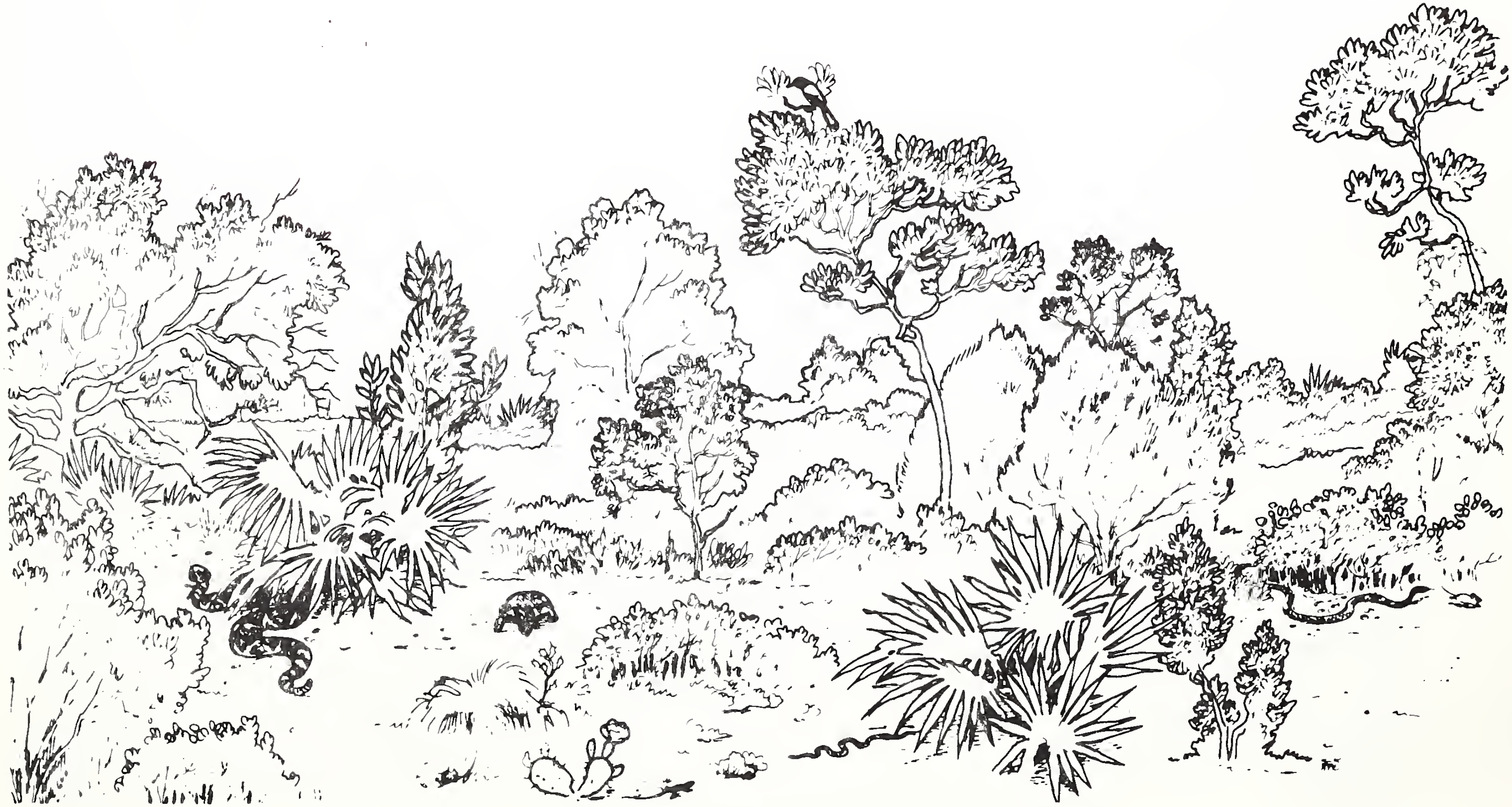

Figure 70a.-Some representative species of a hardwood scrub community.

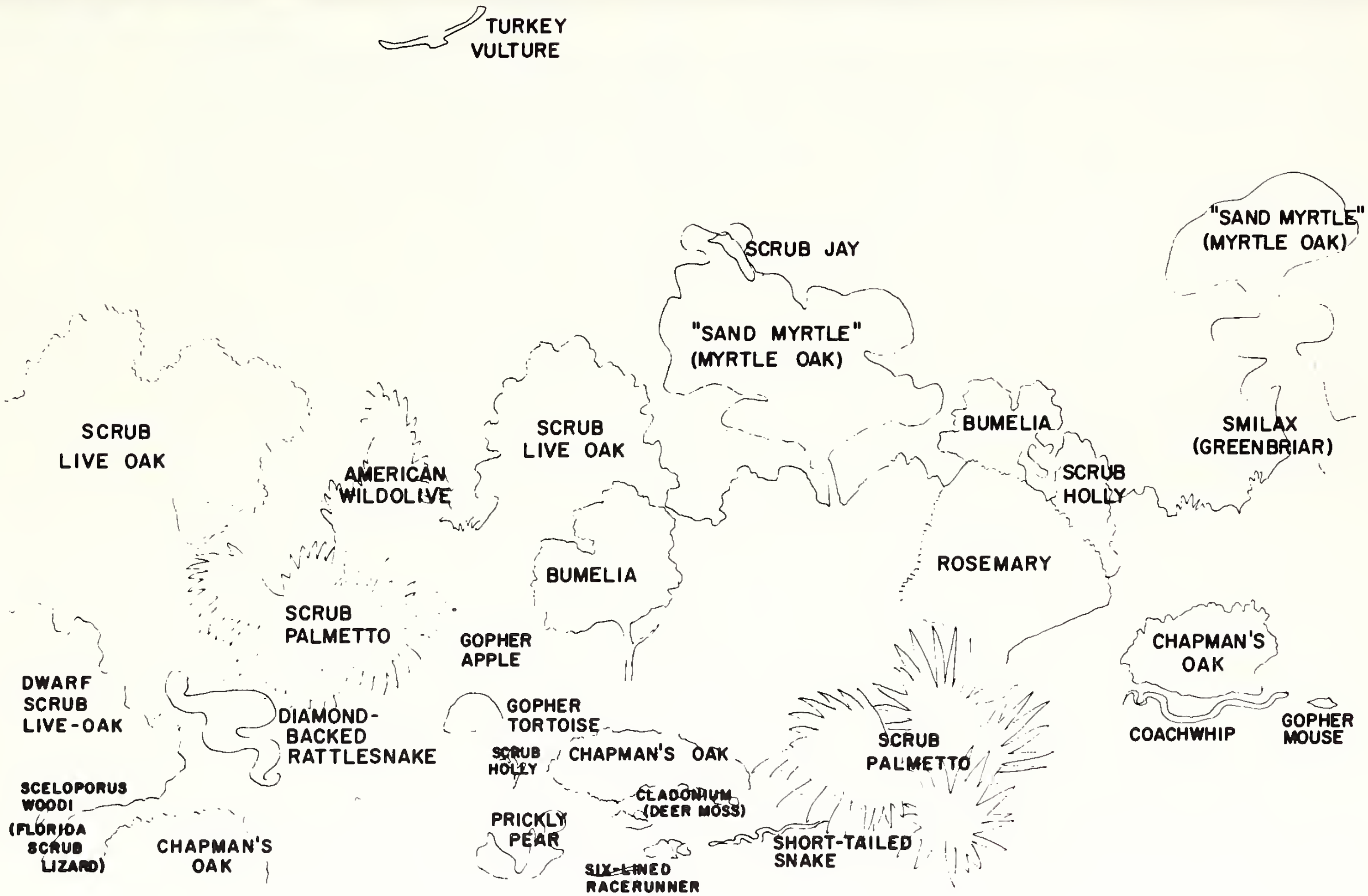

Figure 70b.-Location code for the species in figure 70a.

Serenoa repens - saw palmetto. The saw palmetto is a common component of the drier areas of the Florida landscape and is not restricted to any particular community. The stems have sharp saw teeth. In the scrub, it tends to be more numerous in areas not thickly dominated by sand pine. The berries are an important food for many animal species and were eaten by the Indians, and also has pharmaceutica properties in the treatment of diseases of the prostrate and bladder. Medicinall prepared, the berry juice is an aphrodisiac.?

Persea humilis - silkbay. This small bay tree is characteristic of scrub communities throughout much of Florida. It can be distinguished from other bays by its purplish brown bark and its unusual leaves. Examine a leaf closely and note the shiny, golden-silky underside. Also, crush a piece of the leaf between your fingers and smell the aroma. Many of the broad leaved hardwoods can be distinguished by this once you have become acquainted with them.

Sabal etonia - scrub palmetto. This unusual palm is a component of the scrub and is rarely seen elsewhere. It has a subterranean trunk and about 4-5 palm-like leaves.

Andropogon floridana - Florida bluestem. This bunchgrass is common throughout the scrub and is one of the best indicator species or species that is representative of the scrub.

Ceratiola ericoides - rosemary. At the first glance, the small shrub looks like some sort of conifer with its short needle-like leaves. It may be observed as a common understory shrub (4-6 feet high) under the sand pine and also scattered or clumped on the sandhills. Some folks say the rosemary never lets other plants grow beneath it for it generally appears by itself in small cleared areas. Rosemary is highly combustible and is suggested to provide a way for otherwise small ground fires to leap into the canopy of sand pine trees. The aroma of rosemary is quite evident on hot days. Spice is used for poultry seasoning. It is gathered commercially and used in gardens to provide shade and support for growing the lacy strands of asparagus; also added to boxes of roses sold by florists.

Ilex opaca var. arenicola - scrub holly. The scrub or dune holly is endemic to the scrub communities of central Florida and is easily recognized as it is reminescent of Christmas holly. The leaves are yellowish-green with spiny edges and the berries are bright red.

Chrysobalanus oblongifolus - gopher apple. The fruit of this small woody plant is one of the favorite foods of the gopher turtle. The fruits are considered true plums and are edible. Whereas the gopher turtle consumes the fruit, he is unable to digest the seeds which are scattered along the routes of the tortoise. In this way the gopher turtle obtains moisture and is nourished and the gopher apple is perpetuated as a species.

Cladonia spp. - lichen. There are many species of lichen in the forest and are most common in the scrub and to a lesser extent on the sandhills. Composed of an algae and a fungus (see figure 82), the lichen is a component in the diet of deer. You will notice areas in the scrub where this small whitish plant is dominant. If you are an architect or a model railroader, you will recognize the lichen. It is used by model layout builders to simulate trees or shrubs.

Opuntia spp. - cacti. There are several species of cactus or prickly pear scattered through the scrub and sandhills. In areas of thick underbrush one must choose his steps carefully. The spines of cactus can easily penetrate the leather of one's boots. The bright red fruits of the prickly pear is edible but are somewhat protected from consumers by the two sets of spines, one of which is obvious and the other more difficult to see.

Quercus laevis - turkey oak. The dominant oak of the sandhills occurs frequently in the sub-canopy of the scrub. They are easily recognized in the winter as their brown leaves stand out against the green of the scrub. Only a few species of trees retain their fall-killed leaves throughout the winter. The leaves of the turkey oak resemble a turkey's foot; thus the name. It is interesting to note that the leaves are turned parallel to the sun's rays in order to reduce transpiration.

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Vaccinium myrisinites and V. arboreum - tree huckleberry or sparkleberry. The latter of these two shrubs is valued as an ornamental due to its pleasing shape and the fragrance of its white bell-shaped flowers. Indians used the stems for arrow shafts. They are very closely related to the blueberry of commerce. Wild blueberries may be found scattered in clumps throughout the forest.

Bumelia tenax - bumelia. Look for a scattered shrub which may reach a height of 20 feet tall and whose smaller branches appear thorn-like. Its large leaves have smooth, shiny upper surfaces and are silky-rust color on the underneath. Do not, however, confuse it with the silky bay on the basis of their leaves; the overall appearances of both are quite distinct. The wood of bumelia has good wood-working qualities but seldom is of sufficient size for other than whittling.

Rhus copallina var. leucantha - shining sumac. This is not the poisonous sumac. The shining sumac produces large quantities of small red fruits which form a major part of the dietaries of some seed-eating birds. The foliage becomes red in fall and is very noticeable. To make "Indian tea", crush the berries, soak them in water, and strain mixture through a cloth and serve.

Osmanthus americanus - American wild olive or devilwood. This species may become easy to identify in the field due to its association with a black, sooty fungus which coats older leaves and twigs.

Smilax spp.- greenbriar. Species of smilax are woody vines and occur throughout the Ocala National Forest. For the most part, they are high climbing and possess large (proportionately) woody root stocks. The tenderer parts of the root stock were eaten by the Indians like a potato and the woody parts boiled and pounded to yield a red flour used in puddings. The berries are rubbery and were chewed like chewing gum. Tender sprouts are readily eaten by deer and rabbits and can also be used for salads. In disturbed areas and around forest edges, the tangles of these woody vines, some of which have thorns, make overland hiking difficult and leads to the nickname of Carolina barbed wire. The similar species, probably most encountered in the scrub is S. auriculata.

Ilex ambigua - Carolina holly. The Carolina holly is a small tree that grows up to 15 feet. Leaves are small, thin, and deciduous. Even though this holly is widely distributed throughout the scrub, individuals are generally solitary. The red deciduous berries and early dedicuous leaves distinguish the Carolina holly from its relatives.

Solidago chapmanii - goldenrod

Pityothamnus abovatus - dwarf paw-paw

Garberia fructicora - Garberia. Garberia was named after Dr. A. P. Garber who was the first person to collect specimens for scientific work.

Selaginella arenacola - spike moss.

Panicum patentifolium - warm season, tufted perennials with culms two to four feet tall.

Vitis mumoniana - grape

Polycodium floridanum - buckberry

Rhynchospora clodecandra - beakrush. The beakrush is well named because the nutlet bears a prominent beak.

Galactia elliottii - milk pea. This vine has been named after Stephen Elliott, a distinguished botanists from South Carolina.

Yucca filamentosa - bear grass. If the stringy leaf is braided like hair in three's, it is said to be strong enough to hang a bear. The Indians used the fiber for rope and the flower for food.

Animals

Bufo quercicus - oak toad. Common in older pine forests and in mesophytic hammocks; active during daytime; adults are only 1" long; may be heard calling after warm summer rains.

Bufo terrestris - southern toad. Adults have bumps on head that appear horn-like, common on the Ocala but most abundant in sandy hammocks; may be observed around abnormal concentrations of insects and insect larva, unlike the oak frog, this species is active at night.

Hyla gratiosa - barking tree frog. The largest of the local tree frogs (2-3" long); capable of both burrowing and climbing; common around ponds during breeding season (March to August), otherwise restricted to the drier forest habitats of the Ocala National Forest.

Rana areolata - crawfish or gopher frog. Appearance is atypical for family; appears short and stubby; utilizes abandoned gopher tortoise burrows, mice burrows and crawfish holes; may be observed on branch or log near burrow; wide insect diet and has been known to eat the oak toad (Bufo quercicus).

Ambystoma talpoideum - mole salamander. Head and feet appear disporportionately large for body; also considered rare, adults burrow; breed during warmer periods of winter; lay eggs in the standing water of flatwoods and hydric hammocks during periods of inundation.

Notophthalmus perstriatus - striped newt. Adults inhabit shallow ponds and wet prairies in flatwoods, also hydric hammocks; moderately common in these moist habitats but may also be observed in dry areas near water.

Plethodon glutinosus - slimy salamander. This species is black, 4-6" long, and is relatively common in mesophytic hammocks; skin secretions are glue-like and difficult to remove from hands.

Scaphiopus holbrooki - eastern spadefoot toad. Common in forested areas of sandy or loose soils, mesophytic hammocks and flatwoods; both fossorial and nocturnal and thus seldom seen by the casual observer; breed in temporary rain pools; unmated males make a call-like WARUK-WARUK - a coarse single-syllable sound.

Gopherus polyphemus - gopher tortoise. The gopher tortoise burrows a tunnel 10 to 35 feet for his home, apparently to escape the heat. However sometimes he shares his burrow with burrowing owls, frogs, lizards, raccoons, rattlesnakes, and opossums. The large mound of sand you see in the scrub and sandhills were made by this tortoise.

Sceloporus woodi - Florida scrub lizard. Unlike the fence lizard, the scrub lizard usually escapes predators by racing across the ground instead of dodging around the tree trunks or logs. The scrub lizard can usually be found near or under the aromatic rosemary bush and is native to the scrub.

Cnemidophorus sexlineatus - six-lined racerunners. The racerunner does not climb trees, but that doesn't matter for escape. Sometimes called field streaks, they easily outdistance any would-be collector or predator. They are diurnal, that is, they are active during the daylight hours.

Eumeces egreguis - Florida red-tailed skink. Reddish color of the tail is characteristic, but don't pull on the tail because it might come off. This is an adaptive mechanism to escape predators and is common among all skinks.

Eumeces inexpectatus - southeastern five-lined skink. This smooth, shiny skink lives in a wide variety of habitats, and also climbs well.

Neoseps reynoldsi - sand skink. The sand skink quickly burrows or "swims" through sand under rosemary scrub and sandy pine woodlands. Look for them buried in the sand mound of some burrower. You may not notice the sand skink until you distur the mound.

Drymarchon corais - rare indigo snake. The indigo snake is named for the new blue-black scales that appear after it has shed its skin. If it is threatened, the indigo snake vertically flattens Its neck, hisses and vibrates its tail which rattles among leaves and twigs. Lives in gopher turtle holes in high dry hammocks. Because of their easy temperment and size they are kept as pets. Remember, however, that the indigo snake is protected on the Ocala National Forest.

Crotalus adamanteus- diamond-back rattlesnake. The dark brown diamond shaped coloration is silohuetted on a background of ground color olive or black. The loud buzzing rattle, broad head, and distinguishing diamond-shaped colorations on the back should help in identifying this poisonous snake. It gains a new tail rattle everytime it sheds its skin which happens 2 or 3 times a year. Considered by some to be the most dangerous North American reptile, the diamond-back has more venom, larger fangs, and a greater ability to inject its venom into its prey than the coral snake. The rattlesnake itself is a prey of the "piney-woods rooter" or wild hog.

Coluber constrictor - black snake or racer. Adults are 36 to 78 inches long, slender, primarily black except for the head and neck which are white. From 4 to 40 eggs are laid during June or July and hatch about a month later. Despite the specific name, it is not a constrictor.

Masticophis flagellum - coachwhip snake. These slender, fast moving snakes are found generally in dry flatwoods and gopher turtle burrows. Prey are not constricted, but pressed down by a loop of the body suffocating the prey.

Stilosoma extenuatum - short-tailed snake. As you might have guessed, the tail is less than 10 per cent of the total body length, hence the common name. When alarmed the tail vibrates and then the snake strikes with a hiss, even through it is harmless.

rds

Aphelocoma coerulescens - scrub jay (endemic). This crestless jay has solid blue wings and tail with no white markings. Found only in the scrub region of the Ocala National Forest, this bird has never been reported outside the state of Florida. These birds are relatively tame and you may approach them quite closely.

Colinus virginianus - bob-white. These heavy bodied chicken-like land birds have a short heavy bill; their flight range is not far. When flushed, they fly only a few hundred feet. The bob-white nests in coveys and huddle together in a circle with their tails in the center and heads out. Male bob-white has white throat and eye line. The distinct call, bob-bob-white is whistled about 4 to 6 times per minute. Quail are common in southeast U.S. on abandoned farmlands and in successional brush.

Polioptila caerulea - blue-gray gnatcatcher. Blue-back, eye ring, twitches tail sideways; recognized for its fly catching habit. Its high nasal calls sound like a zpee. Before the leaves emerge in the spring, it is easy to find the nest because it is covered with lichens.

Parula americana - parula warbler. Only species of warbler with yellow throat and blue back. Lives primarily in swamps and builds nest from spanish moss if available. Its song is a buzzy trill or rattle.

Dendroica dominica - yellow-throated warbler. Gray back, yellow throat and breast, nests high in pine trees or live oaks generally where spanish moss is available. Song is loud clear series of tew, tew, tew, tew. Overwinters in Florida.

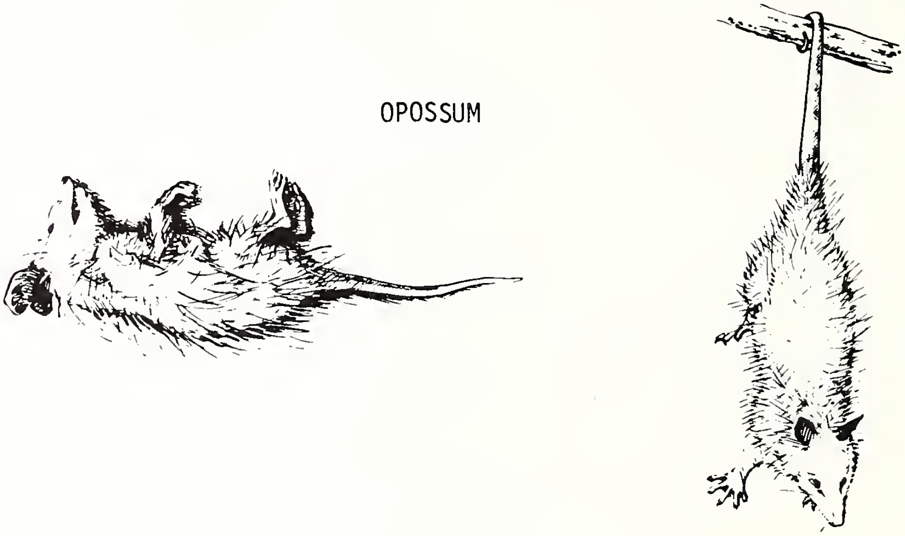
Richmondena cardinalis - cardinal. The Florida cardinal is the only bird found in the Ocala National Forest that is conspicuously red and has a crest; females are drab-colored. Song is a repetition of loud slurred whistles. In the spring and summer, the Florida cardinal eats insects but relies on seeds, fruits, and berries during the fall and winter.

Cathartes aura - turkey vulture. Small red head without feathers, black body and wings; scavenger; soars high in wide circles; holds wings in broad V. Heavy sharp bill helps these flesh eaters to eat live prey. Feeding vultures are joined by other vultures not immediately visible in the vicinity. An interest g defense mechanisms of the vulture is the ability to "vomit" its vile stomach contents, with surprising accuracy, on the molester.

Mammals

Didelphis marsupialis - Opossum. When the young are born, they are about the size of a bumble bee, have no eyes, no fur and no hind legs. Usually 17 or 18 young are born, but only 6 or 8 survive. If you are lucky you might see the young riding on the mother's back holding on to her fur and tail with claws and tail. Opossums eat just about everything - fruits, nuts, insects, dead animals, birds, snakes, fish, frogs and lizards. When threatened they usually faint or "play 'possum". Generally nocturnal, it spends most of its time wandering around in search of food. Enemies of the opossum include dogs, owls, vultures and cars. The prehensil tail enables the 'possum to hang from tree limbs.

OPOSSUM

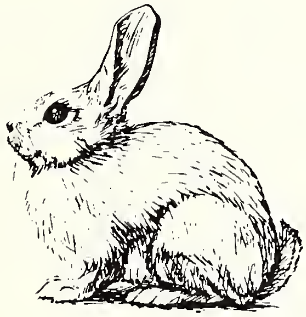


Cryptotis parva - least shrew. Lives in grass-covered areas eating insects, molluscs spiders, earthworms, snakes, frogs, lizards and some vegetable matter. Color of winter fur is peppery in appearance, but changes to brown in the summer. Reported that shrews eat more than their own weight in food each day due to thei extremely high metabolism; chitinous (external skeleton) parts of insects pass through alimentary tract in an hour and half. 4 to 6 litter produced annually; Preyed upon most frequently by owls, hawks, snakes, foxes and other predators. The shrew is one of the fiercest animals and smallest animals known.

Scalopus aquaticus - eastern mole. Moles can be detected by the low ridges pushed up as they burrow through the soil. Narrow pointed head, naked hog-like muzzle, no visible external ears, minute eyes. Diet of earthworms, insects and vegetabl matter. Spadelike forefeet are broader than they are long which is helpful in burrow construction. The fact that the mole only has one litter per year is evidence that it has few enemies. If kept in captivity and not fed for a day the mole will starve to death.

EASTERN MOLE

Sylvilagus floridanus - eastern cottontail. The greyish-brown cottontail carries a distinctive white "powder puff" tail from which it gets its common name. Generally timid and easily frightened, they freeze in a prone position in order to conceal their location. The cottontail lives in heavy brush eating grasses, berries, tender shoots, and sprouts. Tracks of the cottontail are oval in shape with only slight indication of toemarks. Rabbits may hop, leap, or walk. Rabbits have many natural enemies including birds, dogs, skunks, owls, and large snakes; rely on terrific speed for survival. Tularemia is a blood disease that can be transmitted to man by infected rabbits.



EASTERN COTTONTAIL

Glaucomys volans - flying squirrel. Greyish-brown body with white belly. Additional folds of skin connect the front and back legs on either side of the body. When gliding from limb to limb, the extra folds are unfolded adding stability to the flight. Gregarious, and nocturnal; several sharing a nest during the day. Berries, hickory nuts, acorns, insects, bird eggs and young birds are principal foods. Owls, hawks, and household cats are main predators. They are particularly common among the large oak trees in the sandhills. At night, they make a high-pitched squeak which is highly distinctive.

FLYING SQUIRREL

Geomys pinetis - pocket gopher. Furry, rat-like gopher with external cheek pouches which are used for transporting root sections and other bits of food, but are never used for carrying soil to the surface as many people believe. Front legs are very strong with strong claws useful for digging. Capable of running backwards in their burrow with as much agility as when moving foward, tails serve as tactile (sense) organs. Sometimes called a "salamander" because people use to call it a "sand mounder". Usually found in pinewoods or wherever soil is loose enough for easy burrowing. Weasel and gopher snakes are most feared enemies. Roots, underground stems and green succulents are main foods.

Peromyscus gossypinus - cotton mouse. Cinnamon colored, tail half of total length and large hind feet. Omnivorous (consumes both animal and vegetable matter), eating mostly insects, snails, seeds of blueberries, acorns and seeds of conifers. Preyed upon by owls, hawks, rat snakes, skunks and foxes.

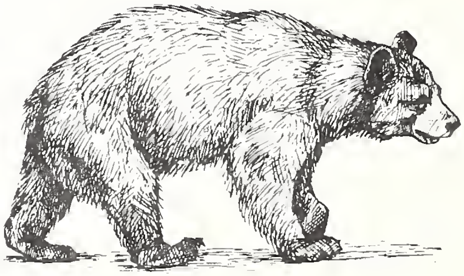
Peromyscus floridanus - gopher mouse. Burrows into the side of gopher turtle burrows, as well as digging its own burrows. Lives in sandy ridges where white sand is exposed in the scrub. Dried seeds, nuts, and berries are favorite foods.

Reithrodontomys humulis - eastern harvest mouse. Rich brown coarse hair, only long-tailed rodent in eastern U. S. with grooved incisors. Builds nest of shredded grass and plant fibers.

Peromyscus polionotus - beach mouse. Likes places uninhabited by humans and places in sand dunes close to salt water. Proficient burrower, constructs nest at end of burrow.

Urocyon cinereoargenteus - gray fox. Three foot long, bushy tail with a fur coat best described as a salt and pepper color. Lives in pine woods, swamps and hammocks, but retreats to den in hollow log or tree for rest. For short distance, speed of 28 mph. Cottontail rabbits, acorns, birds and eggs are favorite foods.

Ursus americanus - black bear. One of Florida's most impressive mammals, the black bear lives in river swamps, scrub oak, large hammocks, and pine flatlands. Black bears eat berries, nuts, honey, insects and small mammals. If you're fortunate you might hear the whimper of an adult calling to her cubs or a woof-woof to warn cubs of danger. Not a true hibernator since respiration is not retarded no does its temperature fall. Usually one litter every two years. The black bear is good at climbing trees. By size alone, the track of the black bear is distinctive. All five toes show distinctly as do the marks left by the claws. Adult bears weigh from 200-300 lbs. and stand more than six feet tall. It is estimated that there are approximately 1000 bears in the state at the present ti



BLACK BEAR

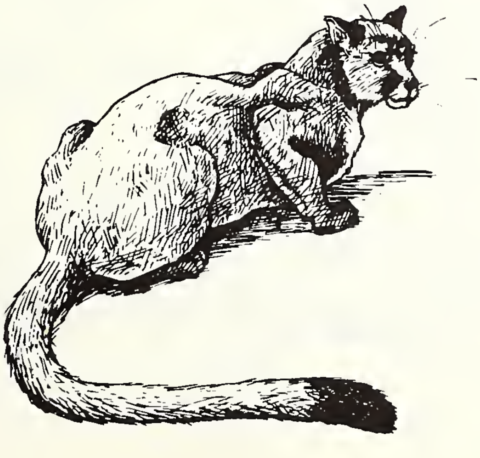
Procyon lotor - raccoon. Yellowish-white rings on the tail and the black mark over the eyes are distinguishing marks of this nocturnal animals, 15-20 lbs., their front paws are like little fingers and they can learn to open screw top jars and doors. Willing to eat almost anything they can find, they usually dip their food in water before eating since the coon has very little salvia. The track of a raccoon resembles a miniature hand and foot print of a human. Raccoon is like the bear in that it finds a warm retreat for winter, but metabolism doesn't decrease enough to call it a true hibernation. Male 'coons eat young.

RACCOON

Mephitis mephitis - striped skunk. Everyone knows the mammal with a black body, narrow white stripe up the middle of the forehead, and gasping odor. Skunks are most active during the night. They eat mice, eggs, insects, grubs, and berries. The scent glands are beneath the tail.

STRIPED SKUNK

Felis concolor coreyii - Florida panther. Pale brown, unspotted cat, 80-200 lbs., lives in swamps and hammocks; rare in Ocala National Forest, favorite food is deer, also eats wild turkey, rabbits, snakes, and skunks. A few panthers will help control deer population by removing weaker animals; sportsmen do not agree.



FLORIDA PANTHER

Lynx rufus - bobcat. This species of cat has a short tail with black only on the top at the tip, mostly nocturnal, eats small mammals and birds. They have reported ranged from 25-50 miles from their den, however a 2-mile radius is more likely. Predators include man, panthers, and alligators.

BOBCAT

Odocoileus virginianus - whitetail deer. These deer are browsers that eat twigs, shrubs, fungi, acorns, and grass. Agility and speed help deer escape predators Top speed of deer have been estimated at 35-40 mph with ability to jump 8.5 feet vertically. Deer live about 16 years under natural conditions. Bucks she antlers after every breeding season, but it will be difficult to find discarded antlers since rodents eat them and are rapidly decomposed. Antlers are the fasters growing bony structures of mammals, attaining full size in about 4 mont. Antler size is not related to age but rather to the quality and abundance of food. Deer tracks are somewhat heartshaped leaving a clean edged imprint. Feeds mostly at night, but active at all times.

The Sandhills

The sandhill community occurs on ridges of well-drained white to yellowish sands of the series Blanton, Astatula and Orlando. In its more perfectly developed form, it is composed of deciduous hardwoods creating an open park-like appearance. Variations in community types may be recognized according to the dominant oak species; turkey oak, the bluejack oak or sand post oak. Longleaf pine was once an important component of the sandhills, but logging has limited it to small areas and scattered individuals. There i usually present an abundant herbaceous ground cover consisting of mixtures of the two wi grasses, Aristida stricta and Sporobolus spp. The most common variant of this plant community is the association of longleaf pine and turkey oak (figure 71).

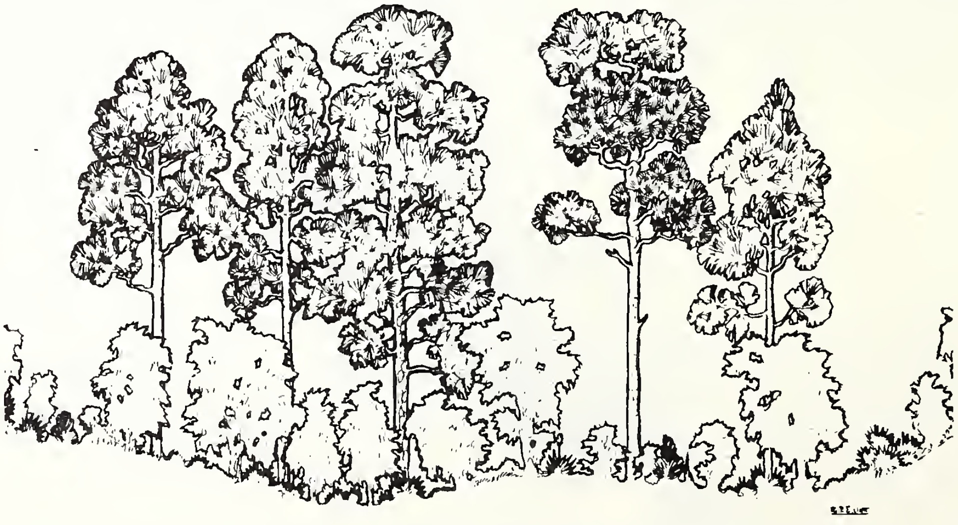


Figure 71. -A profile view of a longleaf pine-turkey oak community. Compare this profile with the profile of the sand pine scrub community in figure 67. Note the openess of the canopy and the ragged crown profile.

Like the scrub, sandhill communities occur on soil resulting from the inundations of
he sea during interglacial periods of the Pleistocene. The soils are not like the dunes
f washed and sorted scrub sands, but rather were developed from beds of non-calareous
ands over beds of sandy acid clay. They may have been submerged by marine waters but
robably not modified before re-emergence. The best developed sandhills, however, occur
n the Citronelle Formation in the Central Highlands where there is present a deep well-
rained layer of weakly washed and sorted sands. In general, the turkey oak variant oc-
upies the drier, more sterile sites and the southern red oak variant occurs in areas where
imestone deposits are close enough to the surface to influence the soil nutrient pool.
e sandhill communities are successional and are fire maintained. On the more calcareous
limestone derived) soils, succession is toward the climax southern mixed hardwoods. The
limax on the more acid sandy soils is toward the live oak climax, itself an expression of
e southern mixed hardwood forest. The successional variants, each with longleaf pine,
re fire-maintained and the climax types are only evident on areas where fire has been
cluded for many years. It has also been suggested that a stimulation in fires may favor
vasion by the scrub if seed sources are present. A diagram expressing these successional
lationships is provided in figure 72.

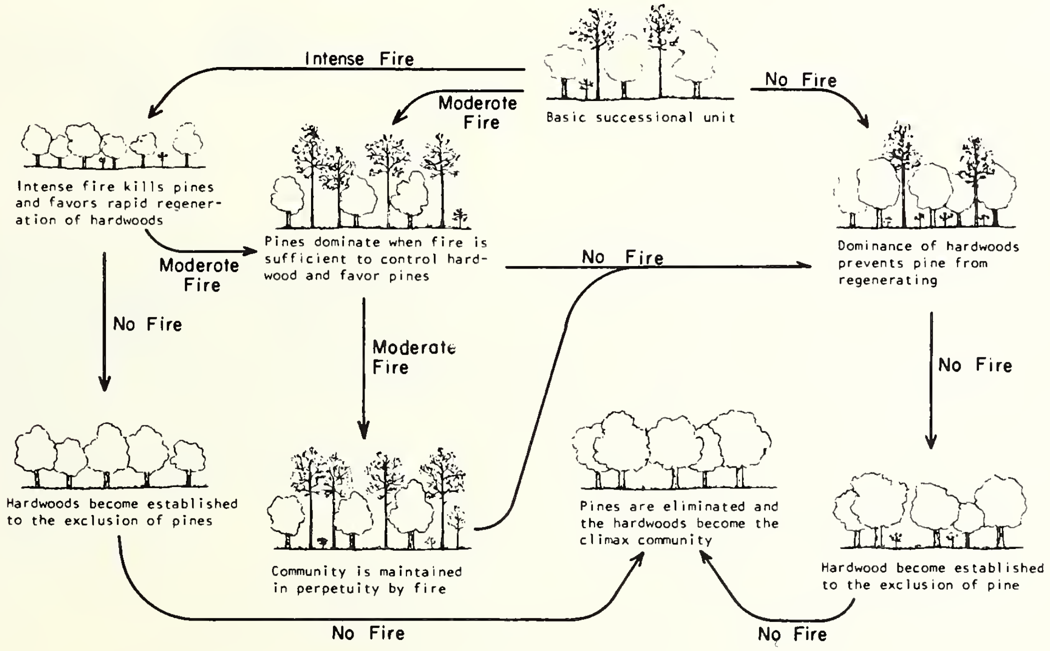

Intense Fire
Basic successional unit
No Fire
Moderote Fire
Intense fire kills pines and favors rapid regeneration of hardwoods
Pines dominate when fire is sufficient to control hardwood and favor pines
Dominance of hardwoods prevents pine from regenerating
Moderote Fire
No Fire
No Fire
Moderote Fire
No Fire
Hardwoods become established to the exclusion of pines
Community is maintained in perpetuity by fire
Pines are eliminated and the hardwoods become the climax community
Hardwood become established to the exclusion of pine
No Fire
No Fire

Figure 72.-The relationship of fire in the succession of sandhill communities. The species composition of the sandhills and their successional status is controlled primarily by fire.

The importance of fire in maintaining sandhill communities, like the scrub, cannot
overemphasized. When fire is eliminated from the sandhills, the oaks increase in size
d the canopy will shade the ground surface. Longleaf pine seedlings cannot develop be-
ath this canopy and thus fail to become a canopy component. Also, the pine seedlings are
sceptible to brown spot, a fungus. Fires which are severe enough to kill back the oaks
ldom harm the fire-resistent pine seedlings, but the heat is sufficient to control the
ngus. Thus, with fire as an aid the longleaf pines are able to compete and become estab-
shed in the community.

When fire is excluded, however, the xeric oaks dominate and prevent pine regenerati As the community matures the microclimate becomes more mesic due to the closed-canopy an a buildup of forest floor litter. These modified conditions favor the more mesophytic o which assume increasing dominance. With the senescence (over maturation) and death of the pines, the community remains as a steady-state climax of hardwoods. Depending on th soil moisture characteristics, the climax varies from xerophytic (dry) hammocks to more mesophytic (moist) hammocks.

The open park-like appearance of the sandhills permits air currents to circulate be the canopy and windrow the litter around the herbaceous ground cover. This exposes the sandy soils to the sun. The natural actions have a drying effect which evaporates water from an environment already functioning with a minimum of available water. Thus, it is not unusual to find many adaptations in this plant community which serve to prevent or minimize water loss. These include heavily cutinized leaves (waterproofed with a waxy material), and leaves whose shapes (linear, revolute, etc.) retard evapotranspiration losses. Probably the most interesting adaptation is found on the turkey oak. During th heat of the day, the turkey-foot leaves turn vertical to the sun, thus minimizing the surface area exposed to this drying agent.

The Components of the Sandhills

The habitat sketch (figure 73) illustrates some of the species which may be observe in the sandhill communities. The reader is referred back to the previous listing for comments on species for which just a name is given.

Plant species of the sandhills:

Pinus palustris - longleaf pine. This species is easily recognized by its long (10 to 15 inches) needles clumped at the ends of the branches and the large yellowish bark scales on older trees. Needles always occur in bundles of three. Seldom will the observer see individual trees of the large size described by the early explorers. Our longleaf pine stands today reflect a long history of naval store operations, logging and a combination of excessive burning and/or fire prevention. Naval stores consist of the tars, pitch, resins and turpentine obtained from southern yellow pines by bleeding the sap from an exposed face cut on the trunk. Longleaf pines were particularly desir for their naval stores and the quality of the lumber which could be cut from large old trees. After the germination of a longleaf pine seed, the seedling remains in the "grass stage" for upwards of 7-10 years. It is called the gras stage because the seedling so closely resembles wiregrass. The seedling, however, can be recognized by its greener appearance and the larger size of the needle leaves. During the grass stage, the seedling is able to withstand ligh ground fires due to the protection of the bud within the center of the needles mass. In fire experiments, a cigarette was placed along side of the bud, and it was only slightly scorched after the fire demonstrating the insulating valu of the needles. At the end of the grass stage, sufficient energy has been stored to go from a wiregrass-like seedling to a sapling up to 10 feet in height. The saplings may be observed standing erect with needles radiating out to form a column almost to the ground level. This rapid height increase clearly takes the sensitive bud to a height where it is above the heat of ground fire. Longleaf pine has the largest pine cone in the south.

Quercus laevis - turkey oak. The turkey oak's greatest expression of dominance is on the sandhills. In some areas of Florida, this previously non-commercial species is being burned to make the charcoal briquets of commerce. Charcoal is made by burning wood within a container that allows only a small amount of oxygen to enter. The woods only smolder and the remains, still capable of burning are pressed into the briquets. Roots from separate trees graft togeth

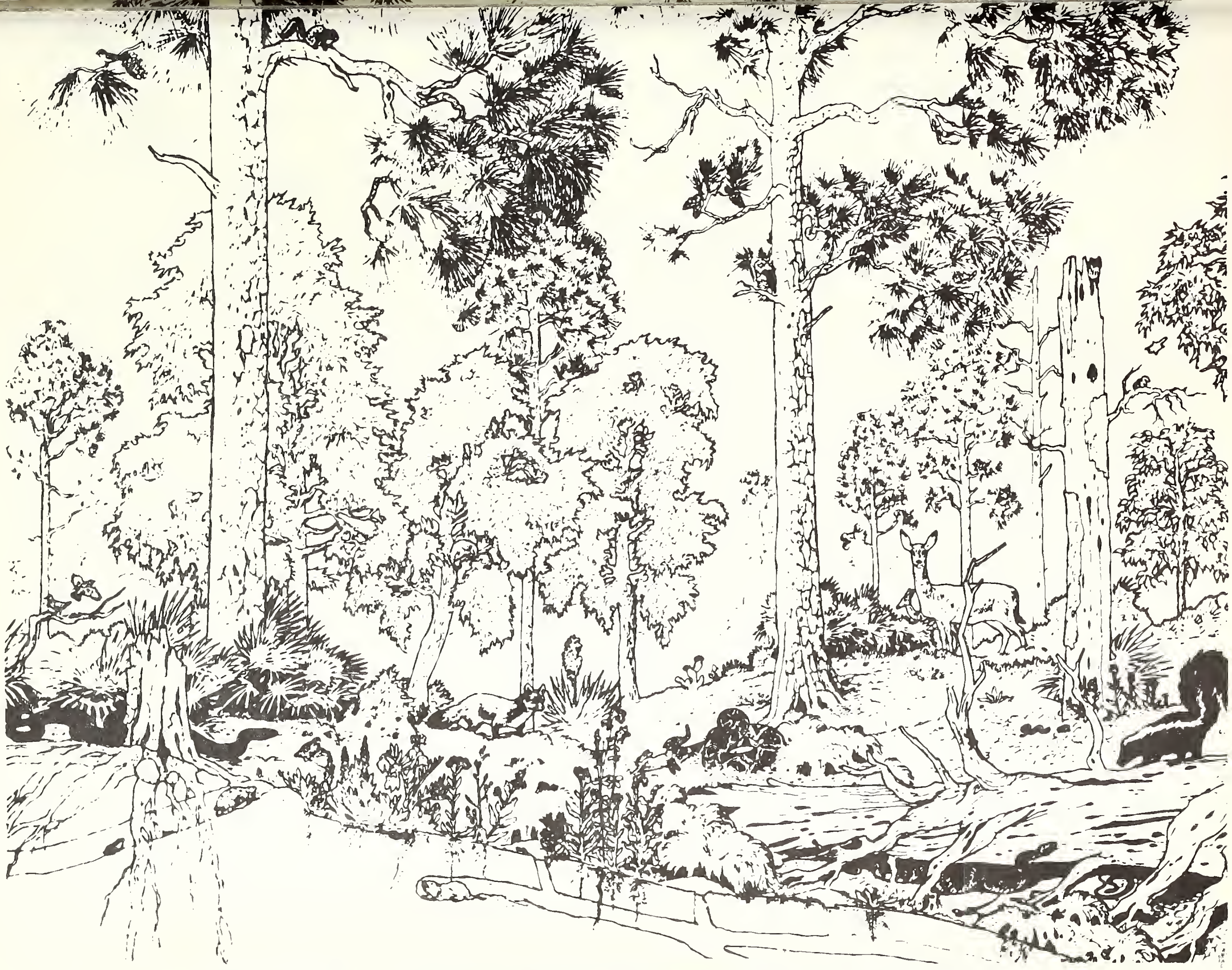


Figure 73a.-Some representative species of the longleaf pine - turkey oak community.

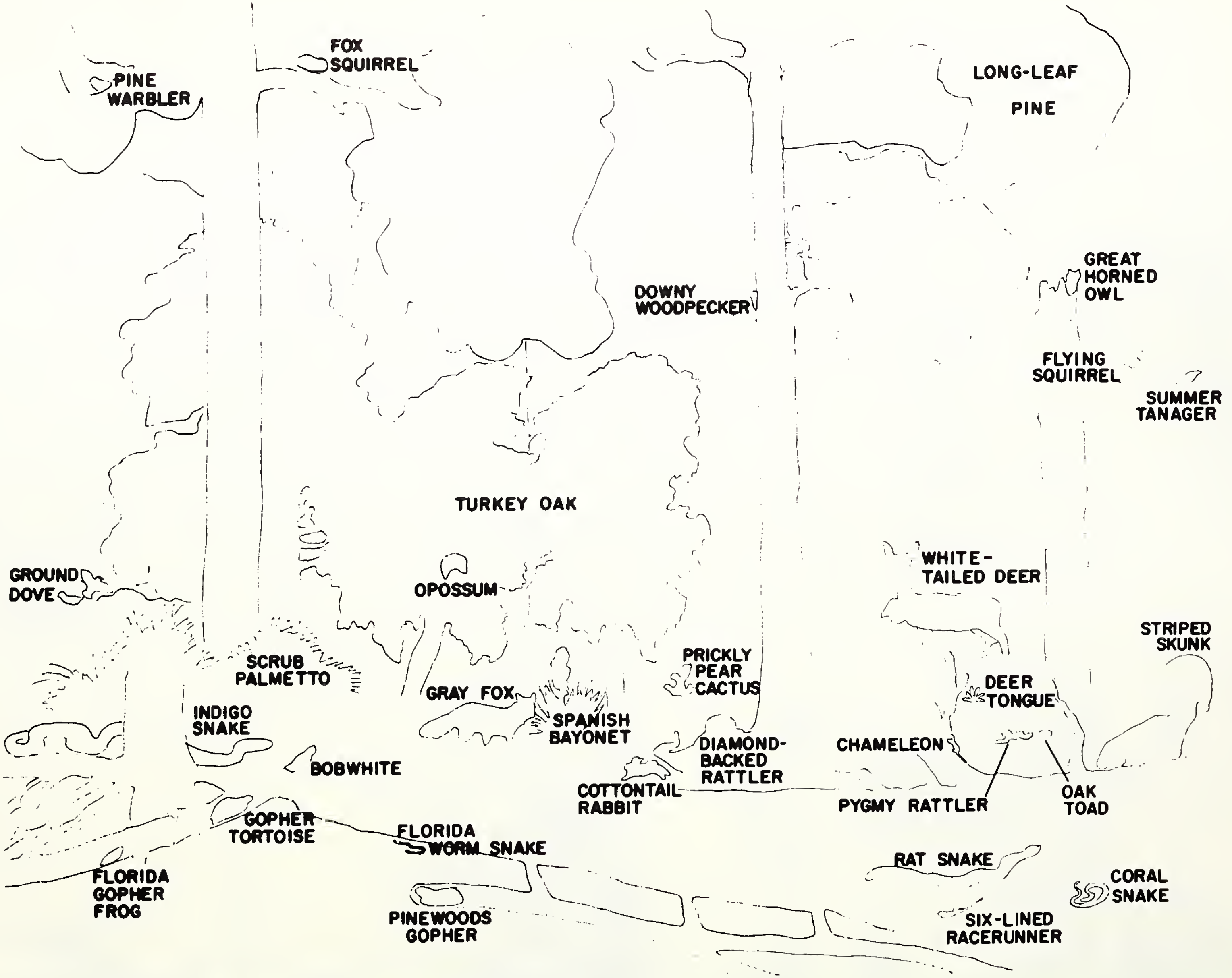


Figure 73b.-Location code for the species in figure 73a.

Diospyros virginiana - wild persimmon. The wild persimmon is a very common species in the drier areas particularly when the vegetation has been disturbed as in an old field or a sandhill after a severe fire. The environmental range over which persimmon grows is extraordinary; it occurs over a wide range of moist conditions, and invades many areas after fire. Like many of the other fire climax species, it has a massive root stock which is not killed by fire and multiplys after fire. The root system makes it a desirable species for controlling erosion in the southeast. The edible fruit was introduced to the DeSoto expedition by the Indians. A green persimmon has a bitterness that would send anyone home with a puckered mouth. After ripening, fruit is quite sweet. The fruit is consumed by many animals. The wood is valued for shuttles (weaving industry) and golf club heads because of its hardness. It is related to the prized exotic wood, eboney.

Quercus virginiana - live oak. Live oak is probably the major climax species in the Ocala National Forest; that is, if the factors responsible for maintaining the various successional communities were eliminated, the resulting climax community would be dominated by live oaks. A mature live oak is easily recognized by its massive size but young individuals are sometimes confused with the smaller variety, the sand live oak (see page 105). The live oak, however, grows in more mesic (moist) environments. The live oak was highly valued by the early Europeans for the structural members in wooden sailing ships. Particularly sought were the massive horizontal limbs which were naturally shaped like keels and ribs. On older trees, this natural shaping is easily observed. Acorns are rich in protein and can be eaten raw or ground. Then tanin is leached out and made into flour. Raw acorns were main food of Jackson's army.

Quercus margaretta var. stellata - sand post oak. The sand post oak occurs on the drier sands as small (around 25 feet, maximum) scattered individuals and as clumps of dwarf (less than 2-foot tall) individuals. These clumps up to 10 feet in diameter are a source of cover for many small animals.

Pinus elliottii- slash pine. This pine, a shade intolerant and fire-susceptible species in its seedling stage, has replaced longleaf pine on large areas protected from fire. Because of its more rapid growth, ease of propagation, and commercial value, it is the principal pine planted over much of Florida. Slash pine is sometimes confused with loblolly pine but may easily be distinguished on needle number per bundle. Slash pine needles always occur in 2's and 3's and loblolly usually in 3's and occasionally 2's. Slash pine is observed in sandhills only on moister soils and in areas close to an established seed source; its major habitat is the flatwoods.

Quercus falcata - southern red oak. Most people have a difficult time distinguishing the southern red oak from the turkey as they are quite similar in appearance and sometimes occur together. The leaves distinguish them in that the base of the turkey oak leaf is flat whereas in the southern red oak it slopes upward toward the leaf tip forming a bill. Site differences also may help to distinguish these two oaks. Southern red oak is usually the species observed in areas where limestone is close to the soil surfaces such as may be indicated by outcrops.

Quercus incana - bluejack oak. In some sandhill communities the bluejack oak may be the dominant scrub oak or may share dominance with the turkey oak. The leaves are similar in shape to those of the live oak but do not have the curled under edges. In the community, the bluejack foliage appears very pale green in color with a faint blue cast.

Myrica cerifera - wax myrtle. Like slash pine, the wax myrtle is a major component of the flatwoods, but does occur in moister areas of the sandhills. It appears as a dense green shrub and is one of the few species that convert (fix) atmospheric nitrogen in a form utilizable by living organisms. The berries were eaten by the Indians and the wax extracted for burning as a light source. This is a plant of many taste sensations; the leaves are aromatic, the bark is bitter and the berries taste like nutmeg. The spicey aroma of the leaves and branchlets are so strong that one may use boughs as a bedding for dogs to drive away fleas, similar to cedar sawdust.

Pinus taeda - loblolly pine. This pine is one of three major southern yellow pines of economic importance: the other two are longleaf and slash. Its occurrence or the sandhills tends to be rare, though in localized areas it may be the dominant pine. Such areas, however, may also be considered not to be true sandhills. The needles occur in groups of 3's (with an occasional 2) which help to distingui it from slash pine. Should you observe two slash-loblolly looking trees, look for a greater abundance of cones on one and denser crown. This will be a lobloll pine.

Crataegus uniflora - hawthorne. In the sandhills look for a small upright shrub with sparse foliage and sharp thorns on the branches. This is the hawthorne of which there are several species in addition to this one, some without thorns. This species provides a protected nesting site for several species of birds. At Christmas time, "sugarplum trees" are created by sticking gumdrops on the thorns of the branches.

Trilisia odoratissima - deer tongue. Deer tongue is a small herb, easily found in the Ocala National Forest, that grows close to the ground and has a slick flat leaf. The dried leaves give off an odor of vanilla when crushed. About two million pounds of deer tongue leaves are collected annually and sold to tobacco manufacturers for filler and aromatic effects.

Animals species:

Amphibians

Bufo terrestris - southern toad

Bufo quercicus - oak toad

Hyla femoralis - piney woods tree frog. Gray, orange spots on hind surface of thigh; adult length 1-3/5 inches. Climbs trees, often found in pine flatwoods. Chorus of voices sound like series of riveting machines all operating at once; series of dot and dashes that sounds like morse code. Relatively common in flatwoods communities and among xerophytic vegetation; sometimes feeds on insects attracted to dung.

Hyla gratiosa - barking tree frog

Rana capito - Florida gopher frog

Reptiles

Gopherus polyphemus - gopher tortoise

Anolis carolinensis - green anole or common "chameleon". At one moment green then changing to a mottled green and finely changing to brown. Attractive green throat fan (dulap) is used as a threatening gesture against predators, but is also used when fighting among themselves. The dulap reddens when the blood capilliaries are stretched when it is exposed. Skin is usually shed several times a year and then eaten. Usually two eggs are buried in shallow loose sand and will hatch in six to seven weeks. Feeds mostly on flies, mosquitoes, caterpillars and moths.

Sceloporus undulatus - eastern fence lizard. If you see what looks like a small pine cone with legs and tails scampering up a tree it is probably a fence lizard. You need two people if interested in catching one because they usually keep a rock or tree between themselves and potential danger. Live in high pine and upland hammock; natural enemies include various snakes, birds, and larger skinks.

Ophisaurus ventralis - eastern glass lizard. Lives in pine woods or wet prairies, eats insects, small snails, lizards, and small snakes, The glass lizard is a favorite food of the king snake. The lizard is legless and moves by "swimming" through the sand.

Eumeces inexpectatus - southeastern five-lined skink

Eumeces egregium - Florida red-tailed skink

Sceloporus woodi - endemic scrub lizard

Rhineura floridana - Florida worm lizard. On first appearance this snake-like lizard looks like an ordinary earthworm. Rarely would you see a worm lizard aboveground except where exceptionally heavy rains or plowing might force them to the surface. Preyed upon by birds mistakenly assuming they are earthworms.

Coluber constrictor - black snake or racer

Drymarchon corais - rare indigo snake

Elaphe obsoleta - rat snake or chicken snake. This rat snake lives in areas where rats and mice may be abundant. Sometimes may be found in upland hammocks living in trees. Newly hatched young are about 12-1/2 inches. Eat rats, mice, bats, birds, chickens, tree frogs and other snakes.

Pituophis melanoleucas - pine snake. A tan or rusty snake adept at burrowing and catching pocket gophers, their favorite food. Besides controlling rodent populations, the pine snake also eats small mammals and birds. Powerful constrictor, up to 8 feet long, feeds on rabbits, squirrels, birds, and eggs. Unlike other egg-eating snakes, the pine snake crushes the egg by muscular contractions after the egg goes about 8-10 inches into the esophogus.

Stilosoma extenuatum - short-tailed snake

Crotalus adamanteus - diamond-back rattlesnake

Masticophus flagellum - coachwhip snake

irds

Colinus virginiana floridanus - Florida bob-white

Polioptila caerulea - blue-gray gnatcatcher

Dendroica pinus - pine warbler. Olive-colored back and wax yellow underparts, tail has two white-patched outer feathers. Feeds almost entirely in pine trees, eat insects, small seeds, berries and green buds. Nests 20-60 feet aboveground, eggs dull white, usually four.

Geothlypis trichas magna - common yellowthroat. Females and immatures are olive-brown with a buffy yellow breast, males have black marks. Distinctive song-witchity-witchity-witchity.

Piranga rubra rubra - summer tanager. One of the frailest birds, about 7 inches long, blood red above, lighter red below, yellow bill. Nest made of loosely woven grasses, stems and spanish moss. Food caught in flight or in upper branches; eats spiders, wasps, beetles, blackberries and huckleberries.

Columbigallina passerina passerina - eastern ground dove. Smallest member of dove family, top of head is deep slate, the bill reddish, grayish-brown back brightened by pinkish-gray below. Usually walks in pairs. Two eggs laid per brood, non-migrating.

Pipilo erythrophthalmus - rufous sided towhee. Large, ground-feeding sparrow, with long rounded tails with large white spots. Frequently seen scratching for insects and seeds in shrubbery or brush. Hop and kick with both feet together, fly close to the ground, pumping their tail. Song is drink-your-tea at the rate of 7-12 per minute.

ammals

Sciurus niger - fox squirrel. This species may be found almost anywhere nuts, seeds and acorns are produced. A newborn squirrel is blind, hairless and helpless. At five weeks of age the eyes are open and the body full furred. At seven weeks, the squirrel is adventurous enough to play and chase through the branches. The fox squirrel, largest of the North American squirrels, is commonly seen in the sandhills.

Spilogale putorius - eastern spotted skunk. This carnivore is black with broken white stripes along the neck, back, and sides. These skunks live in partially wooded areas. To discharge scent, the skunk stands on its front feet and discharges scent directly over its head.
Didelphis marsupialis - opossum
Cryptotis parva - least shrew
Scalopus aquaticus - eastern mole
Sylvilagus floridanus - eastern cottontail
Glaucomys volans - flying squirrel
Geomys pinetis - pinewoods gopher
Peromyscus gossypinus - cotton mouse
Reithrodontomys humulis - eastern harvest mouse
Urocyon cinereoargenteus - gray fox
Ursus americanus - black bear
Procyon lotor - raccoon
Mephitis mephitis - striped skunk
Felis concolor coreyii - Florida panther
Lynx rufus - bobcat
Odocoileus virginianus - whitetail deer

Scrubs and Sandhills

The scrub oaks, the xerophytes in particular, are the climax species of these communities due to their heartiness, the ability to regenerate from root sprouts and seeds in the open or in shade, and their adaptability to a wide range of conditions. They are, however, controlled by fire which tends to favor an arrested succession of pine, or, pine and oaks.

A question among ecologists and naturalists concerns the relationships between the sand pine communities and the longleaf pine - turkey oak community. Both occur under very similar conditions and one may find areas where there is but an invisible line separating the two distinct types. However, when the two occur side by side with a common boundary, the scrub occupies the more coastal location, possibly due to the greater salt tolerance of the scrub vegetation. Of the two, the sandhills are the more fire dependent and there also appears to be a tendency for fire to be less common on the more coastal areas due to the onshore winds Whereas fire may foster the encroachment of scrub into sandhill communities, th reverse invasion has not been observed.

Both the sand pine and sandhill communities are adapted to, and are maintained by fire, although the characteristics of the mechanisms are quite different. In sand pine, when fire occur they burn through the crown destroying the above ground system. Cool ground fires seldom, if ever, occur and it is equally doubtful that they are beneficial in terms of maintaining the system. Thus, the natural sequence is for fire to destroy the sand pine and in the process stimulate regeneration and re-establishment of the community. Thus, we might say that sand pine is maintained through sequences of complete destruction and regeneration.

The sandhills, characterized best by longleaf pine and turkey oak, are maintained by fire, but not through a sequence of destruction and regeneration. This community type is adapted to, and maintained by, frequent fires which burn through the herbaceous ground material without harming the overstory components. The basic structure of the system remains unchanged except for the adaptive responses in the lowest vegetative components and the litter. In analyzing the self-maintaining mechanisms of these communities through biological adaptation to fire, it is evident that the frequency and intensity of fire must be more finely programmed in sandhills than in the sand pine. The wire grass (*Aristida stricta*) provides an excellent example of fire adaptation and the role of one species in the maintenance of a community type.

Wire grass is a most unusual living organisms for scientists have yet to prove that it an reproduce either sexually (requiring male and female forms) or asexually (vegetative re-roduction). Whereas seeds are produced, they are not known to germinate. In spite of its pparent inability to reproduce, it has been, and continues to be, a prominent component of he sandhills and associated variant types. A single clone or clump persists year after year, eing burned over at intervals ranging from one to several years after which new leaf growth ccurs from the root stock. Burning is the only apparent mechanism perpetuating its survi-al. Dense areas of wire grass tend to prevent the establishment of species which would eplace the tree dominants in succession. Those that do become established, however, are sually eliminated by fire. In addition to its role of preventing the establishment of some pecies, wire-grass appears to favor the establishment of others, such as runner-oak. lthough a cause-effect relationship has not been established, it is known that these speci-ic associates seldom occur in areas except where wire-grass is present. Some of these assoc-ates contribute to the diversity of foods for wildlife. Thus, with respect to this one pecies, fire is essential in its maintenance and the perpetuation of its role in maintaining he sandhills.

esophytic Communities: Mixed Hardwoods

The mesophytic hardwood forests are extremely common on the Ocala National Forest but re not as distinctive as the scrub or the sandhills. Also, the variety of species and the ariation in species composition from one area to the next further serves to confuse one about he homogeneous integrity of this vegetation. It is probably best to describe this community s the steady-state (climax) forest which results when succession proceeds normally in the and pine scrub, sandhills and in some variants of the flatwoods community. The particular ssemblages of species and the gross appearance of the mesophytic forest is dependent upon any factors such as the successional initiator, the soil pH, fertility and availability of ater. Drier, sterile areas support mesophytic forests which are dominated by evergreen ardwoods whereas the more fertile areas are dominated by deciduous species. The community ttains the best development in areas where limestone and phosphate deposits appear as outcrops. he richness and diversity of the mesophytic forest community is illustrated in figure 74.

The diversity one discovers in the mixed hardwood climax communities is the basis of ts aesthetically pleasing character and attractiveness. The massive structure of the orest, the richness in plant and animal species and the overall ecological complexity are nique in the elevated areas of the Ocala National Forest. The following lists emphasize hese characteristics:

omponents of the Mixed Hardwood Mesophytic Forest

lant species:

Quercus laurifolia - laurel oak. The laurel oak is a large, rapid growing tree sometimes reaching heights of 100 feet and diameters of three to four feet. The laurel oak has a single straight trunk and lacks the horizontal limbs characteristic of the live oak. The laurel oak leaves are flat and although deciduous do not fall until late in the winter. Its straight trunk and excellent form make it an excellent shade tree.

Magnolia grandiflora - magnolia. The magnolia is named after Pierre Magnol, a botanists, in the 17th century. The magnolia, like the live oak, is one of the conspicuous species in a climax forest. Everyone recognizes the large white flowers and the large dark leathery leaves. Crush a leaf tip and smell the peppery aroma.

Persea borbonia - red bay. Redbay is also called "seasoning bay" because its aromatic leaves have been used in cookery. The hard close-grained wood is suitable for cabinet work, but large, straight timber is difficult to find. The red bay has a shiny upper leaf surface and a paler waxy surface beneath and can be distinguished from the silkbay which has leaves that are shiny and golden silky beneath.

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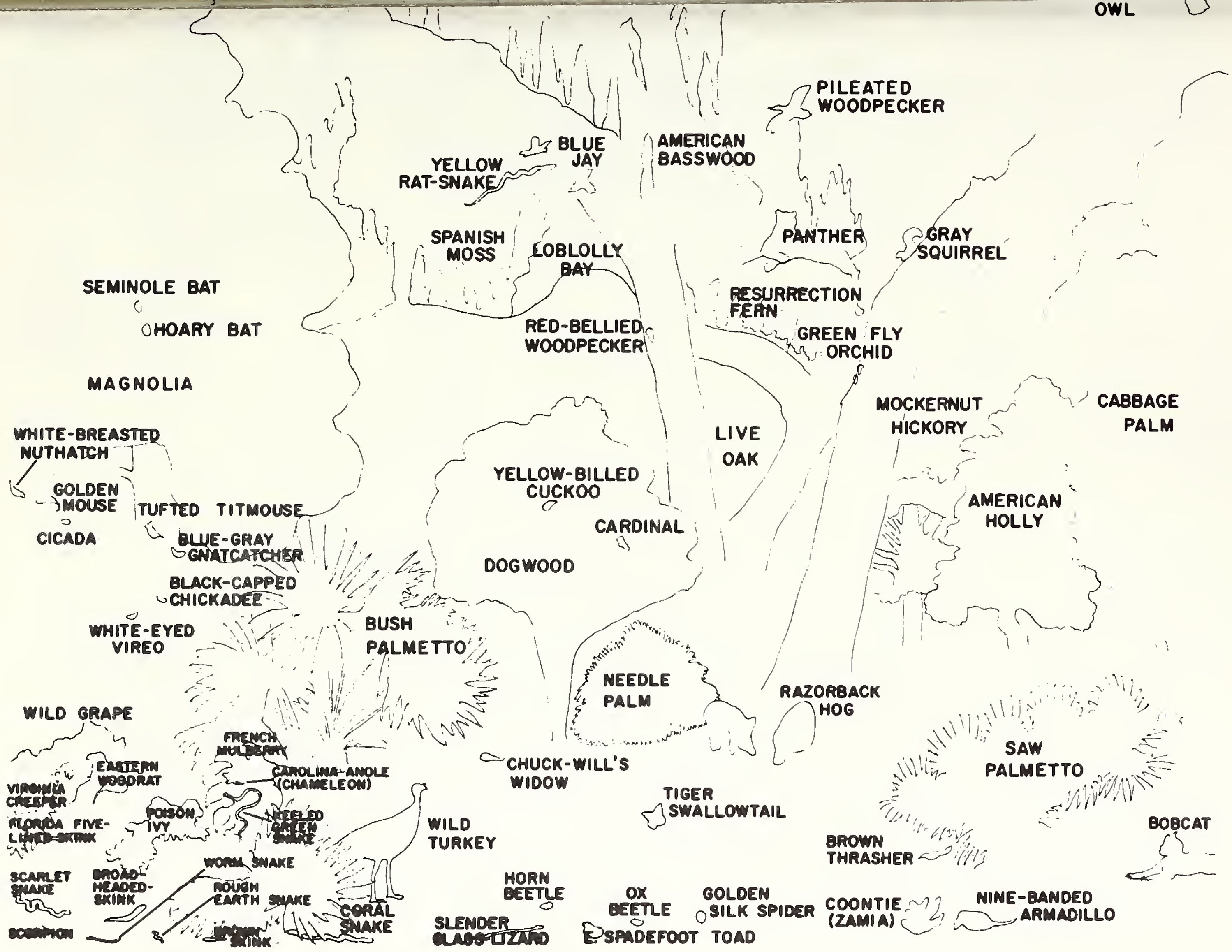


Figure 74b.-Location code for the species in figure 74a.

Ilex opaca - American holly. The American holly has handsome dark green foliage in contrast to the scrub holly which has yellowish-green leaves. In fruiting plants, this foliage characteristic combined with heavy clusters of red berries provides a tree popular both as a cultivated ornamental and as a victim of mutilation for Christmas decorations.

Liquidambar styraciflua - sweet gum or red gum. The sweet gum is one of the largest, most common, and most valuable hardwood timber trees in Florida. The aromatic leaves are alternate, 5 or 7 lobed, resembling a star. Should there be any difficulty in distinguishing a sweet gum from a maple, the latter has non-aromatic leaves oppositely arranged. The wood is extensively used for flooring, interior finish, paper pulp and veneers. The juice (liquid amber) was used as a syrup to sweeten bitter medicines in Europe when sugar was an almost unobtainable spice. This tree is an important source of the drug storax, a stimulating expectorant and weak antiseptic.

Carya glabra - pignut hickory. The pignut hickory is one of the most shade-tolerant trees found in the mixed hardwood forest, that is, it can germinate and grow to the canopy under the darkest shade. The pear-shaped fruits were eaten by the Indians and sometimes pulverized and made into hickory milk by adding water. It is an important wildlife food.

Sabal palmetto - cabbage palm. The cabbage palm is the state tree of Florida and usually grows where limestone is near the surface. The leaves have been used fo thatch and basketry and logs had a variety of uses in building. The cabbage palm has numerous black berries that have a sweet, prune-like flavor which the Indians used for bread meal. The bud is eaten as a salad and considered a delicacy, but results in the destruction of the tree. The branch stubs that are sometimes left on the trunk are called boot jacks because of their similarit to the old time tool used for pulling off boots.

Carpinus caroliniana- American hornbeam or blue-beech. The blue-beech is a small understory tree recognized by the smooth fluting of the trunks which resembles the tense muscles of a horse's leg. The tough, hard wood was formerly used for mallets and wedges, but synthetic materials are replacing it in these uses.

Morus rubra - red mulberry. The red mulberry is confined to low mesophytic hammocks and can be identified by its characteristic milky sap found when leaves are broken. The fruit is frequently used for jellies and pies, but birds and wildlife also like the bright-red juicy berries; seldom does a forest visitor get there first. The leaf is sometimes entire, other times shaped like a mitten with one or two fingers like sassafrass.

Prunus caroliniana - Carolina laurelcherry. The native origin of the Carolina laurelcherry has been overshadowed by its wide use horticulturally. Although the berries provide a food source for birds,animals browsing on the partially withered leaves are fatally poisoned because of the hydrocyanic acid that forms upon withering. Fresh leaves are harmless.

Ostrya virginiana - eastern hophornbeam or ironwood. The tree gets its name from the qualities of the wood and hop-like fruits. Commercially the wood is too small, tough, and difficult to split to be valuable.

Prunus serotina - black cherry. The black cherry grows primarily along fence rows, roadsides or recently disturbed areas. As a close relative to the Carolina laurelcherry, the wilted foliage of the black cherry is also dangerously poisonous to livestock and other herbivorous wildlife. Cherries are very small and almost all the pits are eaten by birds. High value wood for furniture. From the aromatic inner bark a drug is extracted which is used extensively in cough syrups and flavoring.

Tilia floridana - Florida basswood or linden. The basswood, has a very soft wood often used for carving and is usually found as a small tree with several sprouts at its base. It is known to reach heights of 60 feet. The flowers have a sweet penetrating fragrance visited frequently by bees. Basswood honey is regarded as of high quality. The Indians boiled the bark of the basswood which yielded a bast fiber that was used in making cloth ropes, fish nets, and shoes. Easily recognized by unequal shaped leaf bases.

Aralia spinosa - devils-walkingstick. The devils-walkingstick is a shrub or small tree whose stems and leaves are prickly. Colonies are often formed by long underground runners giving the appearance of umbrellas on prickly canes, thus the name devils-walkingstick.

Nyssa sylvatica - black gum or black tupelo. The black gum is a large tree that grows in the upland forest or slopes and may be difficult to distinguish from the wild persimmon. Has dark blue berries eaten by wildlife. The wood used for crates is very tough, hard to work and warps easily. Tupelo honey is a commercially important product in the south.

Cornus florida - flowering dogwood. Because of its attractive shape and dual season attraction, the dogwood is probably the most widely used landscape tree in the state. In the spring the dogwood is covered with many white blooms and in the autumn its foliage and fruits turn bright red. Literally translated from the Latin, "florida" means flowering.

Juniperus virginiana - eastern red cedar. The red cedar is a small tree whose leaves have been used as a stimulant agent to enduce menstrual flow and a tapeworm expellant. Boiled mixture of bark and water has been used for treating bronchitus and skin rash.

Ulmus alata - winged elm. The winged elm gets its common name from the thin corky wings which are usually present on the twigs. The specific name, alata, means winged. These wings form on either side of the twigs during the second year and extend outward about 1/2 inch.

Fraxinus profunda - pumpkin ash. The pumpkin ash is a large tree with buttressed trunks found primarily growing along mucky river swamps.

Ulmus americana var. *floridana* - Florida elm. The Florida elm inhabits wet hammocks and river bottoms, but does not attain the status of the wider-ranging American elm. The winged fruit contains the seed which ripens in the spring and then is widely disseminated by the wind.

Quercus michauxii - swamp chestnut oak, cow oak or basket oak. A large tree, this oak if found in mixed hardwoods of ravines and river bottoms. The species is named after Andre Michaux, a French botanist. The acorns are frequently eaten by cows, thus giving the tree one of its common names. The pumpkin ash, Florida elm and chestnut oak occur in the mesophytic communities only in the wettest areas.

Acer rubrum - red maple. Ranging from a small to large tree, the red maple is conspicuous in the winter because the small red flowers appear before the leaves develop. The leaves are red in the fall and the fruits are red in the spring. Thus the name, red maple. The range of this species extends from Canada to the Florida Keys. Tree may be found standing in water or in slightly moist areas.

Celtis laevigata - sugarberry or hackberry. The berries and seeds of the hackberry provided Indians with food during the winter. It is amazing to look up at the bare tree in the fall after the leaves have fallen and see the tree covered with small red berries. The sweet character of the meaty seed has given rise to the name sugarberry and makes it sought as food by birds and animals. Easy to recognize because of corky warts or ridges on bark.

Quercus durandii - durand oak. The durand oak is a medium sized tree that grows in hammocks on soils high in calcium.

Lyonia ferruginea - staggerbush. The staggerbush is a crooked shrub or small tree. One aid in identifying the staggerbush is its fruit capsule which splits open into 10 parts.

Pinus glabra - spruce pine. The spruce pine has smooth bark and short slender needles that occur in clusters of two. This tall pine occurs mostly as scattered individuals in mixed hardwood stands. Compare this two-needle pine with the two-needle sand pine. Note the abundance of open cones on the spruce pine.

Zanthoxylum clava-herculis - hercules-club, toothache tree, prickly-ash. Hercules-club is a small tree or sometimes a shrub which is well armed with sharp thorns on the trunk, branches, twigs and foliage. The crushed foliage has an orange-like fragrance and the bark was used by the Indians to lessen the pain of a toothache. Place a very small piece of the bark in your mouth and feel the deadening sensation.

Zamia spp. - coontie. This fern-type herb has a thick underground stem which formerly was dug up by the Indians. As a source of starch (Florida arrowroot), the stem had to be ground up and allowed to ferment to eliminate the poisonous materials. The starch was then dried and made into flour.

Tillandsia usneoides - Spanish moss. The Florida scenery is charmed by drooping Spanish moss that waves and weaves in the wind giving the impression that the giant oaks themselves are bending with the wind. Close relative of the pineapple This air plant gets its nutrients from the air and stem runoff. Contrary to popular belief, the Spanish moss is not harmful to trees, but has commercial value since its dry fiber resembles the horse hair that is used for upholstery.

Polypodium polypodioides - resurrection fern. The resurrection fern is an air plant which attaches its rooted runners to tree branches. In dry weather, the resurrection fern looks like brown whiskers as the leaves dry on the branches but shortly after a rain, these whiskers unfold into bright green leaves, thus the common name. Adaptive characteristics allow the fern to live in an otherwise unfavorable habitat.

Rhapidophyllum hystrix - needle palm. Needle palm is a shrubby, dwarf palm that grows in wet habitats in the Ocala National Forest. The tough fiber and long sharp needles provide the thread and needles for clothing of early settlers.

Aesculus pavia - red buckeye. Occasionally large in size, it occurs as a clump of coarse shrubby stems. Red flower conspicuous in the spring; look like small flames or firecrackers. Buckeye nuts are poisonous and were pulverized by the Indians and thrown in streams to kill fish.

Cersium spp. - thistle. Prickly herbaceous plant with pink flower. Flower parts are like fine hair and were used by Indians to tie around blow gun darts to form an air seal.

Rhus radicans - poison ivy. Herbaceous shrub or woody vine. Similar in appearance to Virginia creeper, but has trifoliate (3) leaves rather than five-leaved leaflets. Some people are sensitive to plant; apply drying lotion if rash appears on surface of skin. Smoke is toxic when poison ivy is burned.

Parthenocissus quinquefolia - Virginia creeper
Sabal etonia - scrub palmetto
Serona repens - saw palmetto
Persea lasianthus - loblolly bay
Vaccinium aboreum - tree huckleberry
Osmanthus americanus - American wild olive
Vitis rufotomentosa - wild grape
Carya tomentosa - mockernut hickory
Epidendron conopseum - green fly orchid
Quercus virginiana var. maritima - sand live oak
Myrica cerifera - wax myrtle
Diospyros virginiana - wild persimmon
Pinus taeda - loblolly pine

nimal species

mphibians

Ambystoma tigrinum - tiger salamander. The largest of the four species (7-8" long), rare; burrowing, found in drier habitats of the Ocala National Forest.

Desmognathus fuscus - dusky salamander. Variable in appearance; insectivorous; common near water and moist forest debris. A dwarf race of this species (*Desmognathus fuscus carri*) occurs only in the Ocala National Forest and areas immediately to the south.

Hyla versicolor - common or gray tree frog. An unusually stout, warty-looking frog; seldom observed on the ground except during breeding season; rare on the Ocala National Forest; inhabits hydrophytic swamps and bayheads.

Hyla crucifer - spring peeper. A dark cross appears on the peeper's back; lives near water.

Ambystoma talpoideum - mole salamander

Notophthalamus perstriatus - striped newt

Plethodon glutinosus - slimy salamander

Scaphiopus holbrooki - eastern spadefoot or spadefoot toad

Bufo terrestris - southern toad

Hyla gratiosa - barking tree frog.

eptiles

Terrapene carolina - box turtle. A clever defense of the "land turtles" is their ability to close their shells tightly. The box turtle adapts readily to captivity and is frequently found as a pet with local children.

Anolis carolinensis - green anole or common "chameleon".

Eumeces laticeps - broad-headed skink. This woodland skink makes its home in hollow tree holes usually near springs, swamps or some evidence of moisture.

Rhineura floridana - Florida worm lizard.

Storeria occipitomaculata - red-bellied snake. The plain red belly and light spotted head help camouflage this species in mixed hardwood communities.

Elaphe obsoleta - rat snake or chicken snake.

Eumeces inexpectatus - southeastern five-lined skink.

Cemophora coccinea - scarlet snake. A burrower of soil, usually found in fairly moist soil. Eats lizards, small snakes, mice, insects, salamanders, and turtle eggs.

Carphophis amoenus - worm snake. A good imitation of the common earthworm. Lives in moist soil, rotting logs, under stones. If hand held they attempt to push their way between your fingers. Eats insects and earthworms.

Haldea striatula - rough earth snake. A gray brown snake with a cone-shaped head and distinctly pointed snout.

Lygosoma laterale - brown or ground skink. The burrowing skinks have a transparent disk or "window" in the lower eyelid. This enables them to see when the eye is closed when burrowing in the sand.

Micrurus fulvius - eastern coral snake. The coral snake is a member of the cobra family and should be considered poisonous. It is important to remember the color code - red and yellow bands touch on the coral snake, but in the nonpoisonous snakes the red and yellow bands are separated by a black band. Anterior pair of grooved or perforated teeth in upper jaw for conveying venom. Fangs remain permanently erect; venom effects nervous system.

Ophisaurus attenuatus - slender glass lizards. The tail of these legless lizards may break if hit with a flat object. Sometimes mistaken for snakes, the glass lizard whips back and forth like a racer or whip snake when escaping.

Opheodrys aestivus - keeled or rough green snake. This light green vine snake blends well with the background when it is climbing in trees or bushes and is just about invisible.

Birds

Coccyzus americanus - yellow-billed cuckoo. Slim, long-tailed cuckoo, distinguished by dull brown above and whitish below and yellow lower mandible. Eat hairy caterpillars and are easily seen if there is an outbreak of tent caterpillars. In Ocala National Forest, this cuckoo is only a summer resident arriving in April and leaving in October.

Strix varia - barred owl. Adults, 18-22 inches, round head, large brown eyes (all other owls except barn owls have yellow eyes.) Grayish-brown above and buffy white below; facial disk grayish with concentric bars of brown, yellow beak. Spend the day in the shade of trees and feed at night. Owls that hunt at night a counterparts of hawks which hunt by day. Eats rats, mice, frogs, crayfish, and beetles. Unless disturbed, they frequent the same place year after year. Call is generally five hoo's in the following rhythm: hoo, hoohoo, hoo, hoo.

Parula americana - parula warbler

Geothlypis trichas - common yellowthroat

Richmondena cardinalis floridana - Florida cardinal

Hyla pileatus (also known as *Dryocopus pileatus*) - pileated woodpecker. Spectacular red crest; crow sized, 17-19-1/2". Diggings are large oval or oblong holes. Identified by call: kuk-kuk-kukkuk-kuk-kuk and loud hammering.

Parus bicolor - tufted titmouse. Wings, tail are plain bluish gray; underparts grayish-white, dies marked with a reddish tinge. Crest is gray and pointed. Live in mixed hardwoods, sledom seen in pine flatwoods. Eats acorns, berries, and insects. In winter they have the habit of gathering other small birds arounc them.

Thryothorus ludovicianus - Carolina or Florida wren. Reddest of the Florida wrens. So closely resembles Carolina wren in habit and discription that they cannot be distinguished in the field. Upper body rich, russet brown, wings, and tail finel barred with black, underparts cream buff color. Lives in brushy undergrowth, nesting in hollows in trees and stumps in mixed or swampy woods. Eats insects and supposedly kills more spiders than any other species of wren.

Vireo olivaceus - red-eyed vireo. Small bird, 5-6 inches, has slaty gray cap bordered by narrow black lines, white line above the red eye, and no wing bars, Upper parts are olive-green and lower body parts are pure silky white. Breeds from Gulf of St. Lawrence to the Gulf coast; winters in South America. Diet consists almost entirely of insects.

Sitta carolinensis - White breasted nuthatch. Large-headed, white faced, solid black or gray cap on head. Tree-climbing birds that glean insects from bark of trunks and limbs, commonly seen climbing down a tree trunk head first.

Polioptila caerula - blue-gray gnatcatcher

Parus carolinensis - black capped or Carolina chickadee. Small dickey bird, white cheek patches, gray edging on wing feathers. Non-migratory.

Vireo griseus - white eyed vireo. Only vireo with white iris in eye. Bright yellow sides with gray-green back. Easier heard than seen; song is 5-7 loud notes slurred together ending with emphatic chip.

Meleagris gallopano - wild turkey. Native North American bird with handsome plumage that has a bronze luster. Long, sleek head with considerably less wattling than the head of domestic turkeys. Live in heavy woods or swamps that provide ample cover. After breeding, hen lays 10-12 eggs; eggs hatch 28 days later. Eat acorns, cabbage palm berries, and insects. Florida is reported to have the largest turkey population east of the Mississippi.

Caprimulgas carolinensis - chuck-wills widow. Upper parts are reddish-brown, the low breast a buffy white with bars and streaks of black. The mouth is huge in comparison to the head and body. Bird is crepuscular (active twice a day - dawn and dusk), hiding on the ground during the day completely camouflaged by their protective coliation. Mistakenly called whip-poor-will by most people, but distinguished by the number of syllables in its call, 4 or 6 as opposed to whip-poor-wills 3. The common name is the same as the call except the chuck is often inaudible.

Toxostoma rufum - brown thrasher. A common ground bird, heavily streaked below and rich rufous brown above. Songs are given at the rate of 25-42 per minute.

Bubo virginianus - great horned owls. Large headed, neckless, with feather tufts or horns. Belly is finely barred horizontally. Eyes are fixed in their sockets, so must turn its entire head in order to shift gaze. Most easily seen around dusk. After eating mice, a pellet sized packet is coughed up that contains the skull and bones of the mouse. Hearing is very acute; try squeaking like a mouse and you might attract an owl.

Cyanocitta cristata - blue jay. Blue-winged with white on wings and tail, back grayish violet blue; underparts drab-gray with some white. Call is a harsh scream, sometimes imitates red-tailed red shouldered hawks, causing confusion among the other small birds. They will also gang up and chase away owls and hawks.

Centurus carolinus - red-bellied woodpecker

Dendrocopos villosus - hairy woodpecker. Medium size, vertical stripes on the back. Downy and hairy woodpeckers are the only white backed. Hairy is larger than downy, but checkered, spotted black and white color pattern is very similar, hairy has larger bill.

Dendrocopos pubescens - downy woodpecker. Like all woodpeckers, the downy has a strong beak that acts as drill and a stiff tail that serves as a prop when boring in a tree. Call is a Pik, somewhat softer than the hairy's.

mmals

Didelphis marsupialis - opossum

Blarina brevicauda - short-tailed shrew. Lead colored shrew has no external ears and eyes are so small that they can hardly been seen. Diurnal, they feed on insects, worms and snails. Be careful when handling them because their saliva is poisonous. Shrews produce two or three litters per year, but only live from one to two years.

Sciurus carolinensis - gray squirrel. The gray squirrel makes a loud husky, barking noise when irritated. Nesting in tree holes or branches, it feeds on nuts, seeds and fungi. It has been reported that the gray squirrel will eat about one and one-half pounds of food per week.

Peromyscus nuttalli - golden mouse (also known as Ochrotomys nuttalli). A bright golden cinnamon mouse with a white belly lives in Spanish moss, greenbriar, thickets, or vines.

Neotoma floridana - Florida woodrat. The wood rat is also called a pack rat because he is a confirmed hoarder. It has been reported that he piles palm fronds higher and higher for his nest. Home range for the woodrat is rarely more than 100 yards across.

Sus scrofa - wild boar (razor back). This species has been introduced from Europe and released as a game animal. The upper tusks of the wild boar curve upward, whereas the new world peccary has upper tusks pointing downward.

Dasypus novemcinctus - nine-banded armadillo. The armadillo has been described as a pig in a turtle shell or a rabbit with a malformed head. Being very sensitive to very cold or very hot temperatures the armadillo emerges from his burrow at night or after a rain. It seems as if there are far more numerous burrows than armadillos, but it has been speculated that the extra burrows may be used for food traps. The armadillo forages by smell. The eyes may not be important since they are so small and completely buried when burrowing through litter and soil looking for grubs or ants. For defense, the thick shell is helpful and protects the body when plunging through thorny bushes and tangle. The telltale signs of the armadillo is the dragging tail that seems to imprint a small groove in the sand. The armadillo was introduced into Florida just during World War I when some pets got loose near Hileah, Florida. Later this population was increased when a zoo near Cocoa was destroyed in a storm in 1924 and in 1936 several armadillos escepted from an overturned circus truck near Titsuville. One reason for the present expanded range is the absence or extermination of large predato Alligators are the only known predator in the Ocala National Forest area. Insects comprise 75-80% of its diet. With one swoop of its long sticky tongue 6-70 ants can be consumed. Armadillos have been seen crossing shallow streams walking on the bottom.

Urocyon cinereoargenteus - gray fox
Ursus americanus - black bear
Procyon lotor - raccoon
Mephitis mephitis - striped skunk
Felis concolor coreyii - Florida panther
Lynx rufus - bobcat
Odocoileus virginianus - whitetail deer
Scalopus aquaticus - eastern mole
Sylvilaqus floridanus - eastern cottontail
Glaucomys volans - flying squirrel
Peromyscus gossypinus - cotton mouse

Hydrophytic Communities

Thus far we have described plant communities and representative animals which are adapted to relatively dry conditions (xerophytic) and somewhat moister conditions (mesophytic). In general, they are associated with deep, well-drained sands at higher elevations and are subject to periodic fires. Both the scrub and the sandhills are maintaine in their typical states by fire, the absence of which permits successional development toward a climax hardwood community.

At the other extreme, there are communities which are adapted to constant or periodi inundation by water and, in one particular instance, an interaction of fire and inundati Just as a water deficit may serve as a stress, so does an abundance of water; the mesophytic forest exists under optimum moisture conditions. The hydrophytic communities are those whose particular assemblages of species and structural characteristics are adapted for survival in areas subjected to the stress of a periodic or constant abundanc of water. (Of course, a factor to which an ecosystem is adapted cannot be considered a stress in that particular context.)

Thus, these communities occur at the lowest elevations in the Ocala National Forest and on soils which are poorly drained due to their close proxmity to the water table.

Flatwood Community

The flatwoods community derives its name from usual occurrence on areas of flat topography. It is one of the most common communities found in Florida and there are man examples scattered over the Ocala National Forest in that type of terrain. The flat top graphy represents the area between the old marine terraces and overlain with a thin laye of poorly drained marine sands. The shallow Pleistocene seas covered these inter-terrac areas and deposited the sands. During this era, rivers draining the southeastern porti of the continent (such as the Savanah) carried sediments into the Atlantic Ocean. Here they were caught in the southerly longshore current which flows in the opposite directi of the northerly Gulf Stream. These sandy sediments were then transported and deposited along the peninsula now known as Florida. During each of the interglacial periods of hi water, the sediments were re-sorted and re-distributed by the action of winds, waves an currents. The result is a pattern of shoals, dunes, bars, offshore islands and areas flat topography. Whereas the flatwoods are generally restricted to these marine bottoms the variations in form reflect differences in geologic history and the more recent modif cations due to weathering and interactions with living organisms and fire.

There are many soil series (see Table 7) associated with flatwoods community types nd for the most part are characterized by extremes in internal and surface drainage. nlike the high pH soils of calcareous origins, flatwoods soils are characterized by a ow pH (high acidity) and the common presence of a hardpan. The hardpan results from the luctuations of the high water table. Here, organic materials accumulate creating, iterally, a hardpan beneath the soil surface. The organic pan is highly acid and its resence has a marked effect on plants by retarding growth. Forest managers in Florida ave thought that by breaking up this pan by, for instance, deep plowing, improves the ite quality of flatwood forests. However, this is expensive and thus seldom practiced.

One of the major modifying influences in the flatwoods is the interaction of the easonal precipitation and the flat topography, organic hardpan and sandy soils. The flatoods tend to flood during the summer rains due to the poor drainage characteristics retardng downward percolation and run off. During the relatively dry winter and spring, the high vaporation drys the environment. It is interesting to note that the inability of plant oots to grow below the hardpan makes the water below it essentially unavailable to the orest community. Upward water movement through the pan by capillary action is also much educed. The net effect of low precipitation, high evaportranspiration and the subsequent rying results in an increased probability of fire taking hold and burning large areas. nlike the scrub, however, such fires are relatively cool ground fires, in comparison, nd seldom destroy the entire community. Man's efforts in protecting forests from fire ould not allow the ground fuel to burn off periodically. To prevent a buildup of such uel and thus reduce the prospects of a really hot fire, our forest managers regularly onduct controlled burns in the flatwoods forest type. Not only does this remove the ccumulation of forest fuels but is also beneficial in that fire releases the nutrients mmobilized in the organic material. The effect is similar to adding fertilizer. An dded benefit is the control of palmetto which can cover an area to the exclusion of all ther species. Palmettos are also highly combustible such that heavy stocking produces ery hot fires which are destructive to the system. However, even under these circumstances egeneration of some variant of the flatwoods is assured.

The flatwood community may be divided into three variants based on the dominance of ne of the three most common southern yellow pines: longleaf, slash and pond pine. Longeaf pine flatwoods dominate the drier sites and may be considered a transition community inking the longleaf pine - turkey oak sandhills and the wetter flatwoods. In terms of he floristic composition, this variant is composed of species commonly considered to be omponents of the sandhills and the slash pine flatwoods. The longleaf community in all f its expressions, however, is much altered due to the value of longleaf wood products hich has resulted in heavy harvesting.

The slash pine flatwoods are less perfectly drained than the longleaf variant but re not flooded for as long of periods as is the pond pine variant. In many respects the radations between slash-pine and pond-pine flatwoods variants are as common as the ypical variant. Thus, unless the community is dominated by a single pine species, it s sometimes difficult to distinguish one from another.

In terms of flatwood succession toward some other community type, the frequency and ntensity of fire is the dominant controlling agent, but more recently, man's activities n land drainages have added a new factor in the selection of component species. On he drier sites occupied by longleaf flatwoods, the elimination of fire allows succession o proceed toward the mesophytic mixed hardwood climax. On the driest sites, the result s a mesic, almost xeric, community dominated by live oaks. Slash pine flatwoods, in he absence of fire, may succeed either to the more mesic hardwoods, or in wetter areas, oward the bayhead. The succession of the pond pine community frequently results in the ayhead. In all of these instances succession permits hardwoods to replace the conifers s the community dominant.

In the absence of fire, the fire-maintained pines give way to hardwoods. The improv physical soil conditions (i.e., better moisture balance, aeration and increased microbial activity) benefit both pines and hardwoods, but only hardwoods are able, in general, to become established in the shade of a developed forest canopy. Only the presence of fire creates the overall conditions which favor pine. To an increasing extent, however, the elimination of periodic flooding favors hardwoods over conifers although under certain circumstances, the reverse may appear to be true.

Components of the flatwoods communities:

Plant species:

Quercus nigra - water oak. The water oak is a frequently observed member of the flatwoods although it is more commonly found in wetter areas such as the bottom lands. It is a relatively short-lived species of oak although it is planted as a shade tree.

Magnolia virginiana - sweet bay. This tree is similar to the magnolia, particularly the flower which is much smaller but equally as fragrant. The sweet bay sprouts quickly after fire and is considered in this regard, a successional species.

Gordonia lasianthus - loblolly bay. This bay is closely related to the Asian tea plant of commerce. Its shallow root system is suggested to be the reason for its short life span.

Ilex cassine - dahoon or holly. Because the leaves are not conspicuously spiny, dahoon is rarely recognized as part of the holly family. However, dahoon is used widely during the holiday season that is commonly called Christmas berry. American holly usually occurs on well drained sites whereas the dahoon is found in wet habitats. The Indians used the caffeine containing leaves for tea.

Myrica cerifera - wax myrtle
Pinus elliottii- slash pine
Pinus palustris - longleaf pine
Lyonia ferruginea - lyonia tree
Acer rubrum - red maple
Quercus virginiana - live oak
Quercus laurifolia - laurel oak
Nyssa sylvatica - black gum
Pinus serotina - pond pine
Diospyros virginiana - wild persimmon
Liquidambar styraciflua - sweet gum or red gum
Magnolis grandiflora - magnolia
Befaria racemosa - tar flower

Amphibians

Gastrophryne carolinensis- eastern narrow-mouthed toad. Grayish brown, small toad. Lives in a wide variety of habitats generally near moisture such as swamp borders. Voice resembles bleat of lamb. Breeds in shallow water.

Acris gryllus - cricket frog. A non-climbing member of this family; very common around shallow water surrounded by vegetation; will attack insects too large to swallow; may be found during any month of the year in the Ocala National Forest.

Hyla cinerea - green tree frog or rain frog. Believed to signal the onset of rain for laymen but not for scientists; quite common on vegetation near water, on floating or emergent aquatic vegetation and on palm and palmetto leaves; adults are around 2" long.

Hyla ocularis - little grass frog, swamp tree frog,or least tree frog. The smallest of the U. S. frogs (less than 1" long); can turn their heads without moving their bodies; common in grassy areas particularly around cypress trees; also known as *Limnaoedus occularis*.

Pseudacris nigrita - chorus frog. Infrequent climbers, primarily on small plants; relatively common in low swampy areas but also occurs in other moist to wet habitats.

Rana pipiens - leopard frog. In the summer the leopard frog wanders well away from the water and is sometimes called the "meadow frog".

Scaphiopus holbrooki- eastern spadefoot

Bufo terrestris - southern toad

Hyla femoralis - piney woods tree frog

Hyla gratiosa - barking tree frog

Bufo quecicus - oak frog

ptiles

Rhadinea flavilata - yellow-lipped snake. The golden brown to light reddish brown body coloring and a dark line through the eye is characteristic of this species.

Terrapene carolina - box turtle

Anolis carolinensis -green anole or common "chameleon"

Sceloporus undulatus - eastern fence lizard

Ophisaurus ventralis - eastern glass lizard

Eumeces inexpectatus - southeastern five-lined skink

rds

Buteo lineatus - red-shouldered hawk. Reddish-brown coloration above and lighter reddish-brown below; "shoulders" are chestnut wherein it gets its name. 18-22 inches long. In flight the sharply defined narrow bars of white or brownish black tail are recognition marks. Food consists of mice, rats, snakes, and insects.

Grus canadensis - sandhill crane. Adults are 40-48 inches, have long black legs, a long neck, gray plumage and a bald forehead. Neck fully extended in flight, wingspan 6-7 feet. Unlike most herons, spends lot of time on the ground gathering food - roots, bulbs, insects, frogs, lizards, snakes, and mice. Nest found on knoll, thus enabling it to see enemies coming from great distance. Long sharp bill is good protection against predators. Long windpipe produces a resonant cry heard for long distances.

Dendrocopos borealis - red cockaded woodpecker. White bars on a black back, white spots on wings and white under parts, Red feathers on both sides of the black crown. Home is drilled in live pines from 20-70 feet high. Food is usually found in pine trunks that harbor wood-boring beetles, larvae, ants, crickets, grasshoppers, and seeds.

Sitta pusilla - brown-headed nuthatch. Lives almost exclusively in pine and is often seen climbing down pine trunks head first. Nest is an excavated hollow in a rotting pine stump, occasionally 50-60 feet up in a giant pine. Unlike the pine warbler who gleams twigs and clumps of needles, the nuthatch searches the trunks and larger branches for beetles, ants, cockroaches. Pine seeds are their only plant food.

Sturnella magna - eastern meadowlark. Brown upper parts, streaked with black, underparts are yellow, with a black "V" across the breast; outer tail feathers are white. Nest is done of grass that is usually built on prairies, or meadows. Food consists of grasshoppers, beetles, bugs, and caterpillars.

Colinus virginianus - Florida bob-white

Parus bicolor - rufted titmouse

Polioptila caerulea - blue-gray gnatcatcher

Dendroica pinus - pine warbler

Richmondena cardinalis - Florida cardinal

Mammals

Sylvilagus palustris - marsh rabbit. The marsh rabbit is primarily nocturnal living in marshes as their name implies. Diet consists of fish or roots and bulbs of marsh vegetation.

Oryzomys palustris - rice rat. The rice rat is nocturnal, semi-aquatic, feeds on green vegetation and seeds and nests under debris above high water levels.

RICE RAT

Sigmodon hispidus - cotton rat. Feeds primarily on green vegetation, but occasionall eats eggs of ground nesting birds. It is rare to find a cotton rat that has lived more than one year in the wild.

Didelphis marsupialis - opossum
Blarina brevicauda - short-tailed shrew
Cryptotis parva - least shrew
Scalopus aquaticus - eastern mole
Sylvilagus floridanus - eastern cottontail
Sciurus niger - fox squirrel
Peromyscus gossypinus - cotton mouse
Peromyscus nuttalli-(also known as Ochrotomys nuttalli) - golden mouse
Urocyon cinereoargenteus - gray fox
Ursus americanus - black bear
Procyon lotor - raccoon
Mephitis mephitis - striped skunk
Felix concolor coreyii - Florida panther
Lynx rufus - bobcat
Odocoileus virginianus - whitetail deer

Mixed Hardwood Swamps

Of all of the hydrophytic communities of the Ocala, the mixed hardwood swamp is one the most impressive. The two best examples are found along the Oklawaha River system an at the extreme southeastern end of the forest next to Lake George. The swamps, however, may be observed along the majority of the creeks (Juniper and Alexander Runs, for instanc rivers, sloughs and in areas that are seasonally flooded but remain moist during the dry season. The swamps are dominated by deciduous hardwoods of impressive size and forms. For the most part, the mixed hardwood swamp sites are relatively high in calcium and magnesium and have an excellent balance among the other nutrient elements. Like the mesophytic mixed hardwood community in drier areas, the hydrophytic swamp is the climax in areas that are seasonally flooded. Succession in the slash and pond pine flatwoods (wet variants) and cypress swamps may result in either this community or the bayhead.

Plant components of the mixed hardwood swamps:

Fraxinum carolinana - pop ash or swamp ash. The pop ash is a medium size tree component of lowland areas which are inundated for long periods of time. Its crooked or leaning trunk is characteristic.

Sambucus simpsonii - elderberry. The shrub is extremely common along unshaded cree banks and in disturbed wet areas. The Indians used the hollow stems for whistles and maybe even straws. The latter is doubtful as the stems are poisonous and may cause nausea.

Taxodium distichum - bald cypress. The bald cypress is a large tree sometimes with buttressed trunks that grow along slow moving streams, floodplains, or limestone soils of swamps. The "knees" of the bald cypress are sharp at their tips whereas more of the pond cypress are rounded and blunt at their tips. The height of cypress "knees" is in direct proportion to the amount of fluctuation of the water table. Bald cypress surpasses all other Florida trees in longevity, some have been reported as much as 1300 years old. Cypress is one of the few conifers that looses its leaves during the winter. The wood is very durable and resistent to rot. The Indians used cypress trunks for dugout canoes

Cephalanthus occidentalis - common button bush. The buttonbush is a scrubby shrub because the leader shoots are dying stumps. The white flowers resemble pin cushions. The distribution of this shrub is confined to wet areas and thrives best around ponds where it stands in shallow water.

Gleditsia aquatica - water locust. Water locust, an inhabitant of floodplains and river banks is characterized by its pinnate leaves and compound thorns. These thorns have been reportedly been used for early phonograph needles. The pulp of the pod can be eaten, but the seeds are toxic as are many other legumes.

Ilex vomitoria - yaupon holly. The scientific name is derived from an old Indian practice of brewing the berries to produce a strong drink which would induce vomiting during ceremonies.

Acer rubrum - red maple
Ilex cassine - holly or dahoon.
Nyssa sylvatica - black gum
Sabal palmetto - sabal palmetto
Quercus nigra - water oak
Ulmus floridana - Florida elm
Myrica cerifera - wax myrtle
Liquidambar styraciflua - sweet gum or red gum
Pinus palaustris - longleaf pine
Carpinus caroliniana - American hornbeam
Quercus laurifolia - laurel oak
Aronia melanocarpa
Vaccinium arboreum - tree huckleberry
Rhus radicans - poison ivy

Bayhead Communities

Bayhead communities take the name of the bay trees which are invariably found in this community. The world's largest known individual bay tree is found on Hugh's Island in the scrub. Trees of the bayhead are dominated by broad-leaved evergreens which thrive on the high organic matter and soils which are subjected to seasonal flooding. Unlike the swamp community, the bayhead are characterized by an accumulation of peat which is prevented from oxidizing away by the anaerobic waters. Succession is from bogs, marshes, swamps or pone pine flatwoods.

Plant species components of the bayhead communities:

Magnolia virginiana - magnolia
Pinus palustris - longleaf pine
Gordonia lasianthus - loblolly bay
Myrica cerifera - wax myrtle
Nyssa sylvatica - black gum
Pinus elliottii - slash pine
Vaccinum arboreum - blueberry
Ilex cassine - holly or dahoon
Liquidambar styraciflua - sweet gum or red gum
Quercus nigra - water oak

Cypress dome communities

Although cypress dome communities are not found on the Ocala, they are an extremely interesting natural feature due to the reasons for their occurrence. Cypress domes occu in areas of low topography over a lens, or pan, of impervious clay. Unlike the organic pan of the flatwoods, the clay pan holds waters within the confined area of the dome and thus seldom dries to the extent evidenced in the surrounding flatwoods. The availabilit of water in these domes during all but the driest years makes them a sort of refuge for animals of adjacent communities during period of drought or fire. The characteristic cypress in the dome is the pond cypress, which in general is restricted to sites with an acid (low) pH. Succession in cypress domes leads to either bayheads or the mixed hardwood swamp.

From the air the cypress dome communities appear circular in shape evidencing that many of them occur over very old sinkholes that have progressively filled in over time. From the ground, the rounded dome appearance is due to the larger cypress trees occurrin in the center with progressively smaller trees radiating toward the perimeter.

Plant species components of the cypress dome communities:

- *Taxodium ascendens* - pond cypress. The pond cypress never reaches the size of the bald cypress and occurs primarily in vegetation domes. The oldest and largest trees are always in the center with the youngest and smallest on the perimeter.
- *Nyssa sylvatica* - black gum
- *Taxodium ascendens* - pond cypress
- *Myrica cerifera* - wax myrtle
- *Pinus elliottii* - slash pine
- *Cephalanthus occidentalis* - common button bush
- *Magnolia virginiana* - sweet bay
- *Acer rubrum* - red maple
- *Ilex cassine* - dahoon or holly
- *Pinus palustris* - longleaf pine

One seldom thinks of bats as being components of terrestrial communities, for we usually associate them with caves and old houses. However, bats through their feeding habits are closely tied to non-cave communities and occur throughout the Ocala National Forest. The bat is the only flying mammal (flying squirrels just glide) and in Florida (see p. 196 for listing) are primarily insectivorous, that is they feed on insects (moths beetles, mosquitoes, etc.). They are active during the night and catch flying insects wi the aid of their built-in radar. The procedure is called "echo location" whereby the bat emits a signal and the "echo" pinpoints solid objects such as insects. Most bats hiberna during winter, but in Florida the caves are so warm (around 69° to 73° F) and insect populations sufficiently adequate, that they remain relatively active. Roosting cave colonie may be large (up to 90,000 in one cave reported for the little brown bat). The major predators of the bat are owls and snakes, particularly for ones which roost in the forest - look for small colonies in hollow trees. Bats bite and scratch and are known to carry rabies so it is probably best not to handle them.

Aquatic communities

Scattered throughout the Ocala National Forest and bounding it on three sides are a large variety of aquatic communities. These communities occur in springs, creeks, rivers, lakes, ponds, wet prairies and impoundments such as the Rodman reservoir, and in water that ranges in color from crystal clear to black and in salinity from fresh to salt water. The number of combinations of physical environments described by topography, source of water and water quality is reflected in the large number of aquatic community types. When the Ocala National Forest is considered in its entirety, the diversity of communities and biological components make it one of the ecologically most interesting regions in the state. As the reader may now recognize, the diversity is closely related to the distribution of water over the landscape and through the seasons.

The specific biological composition of each of the various aquatic communities is closely related to the quantity and quality of water, which are to a large extent a function of topography. Let's examine these characteristics with regard to what we have learned about communities and environmental influences. The following is a listing of the major classes of aquatic environments commonly found in the region:

(1) Springs - There are two basic kinds of springs which are defined according to the origin of the water (Figure 75). In some of the elevated portions of the Ocala National Forest,

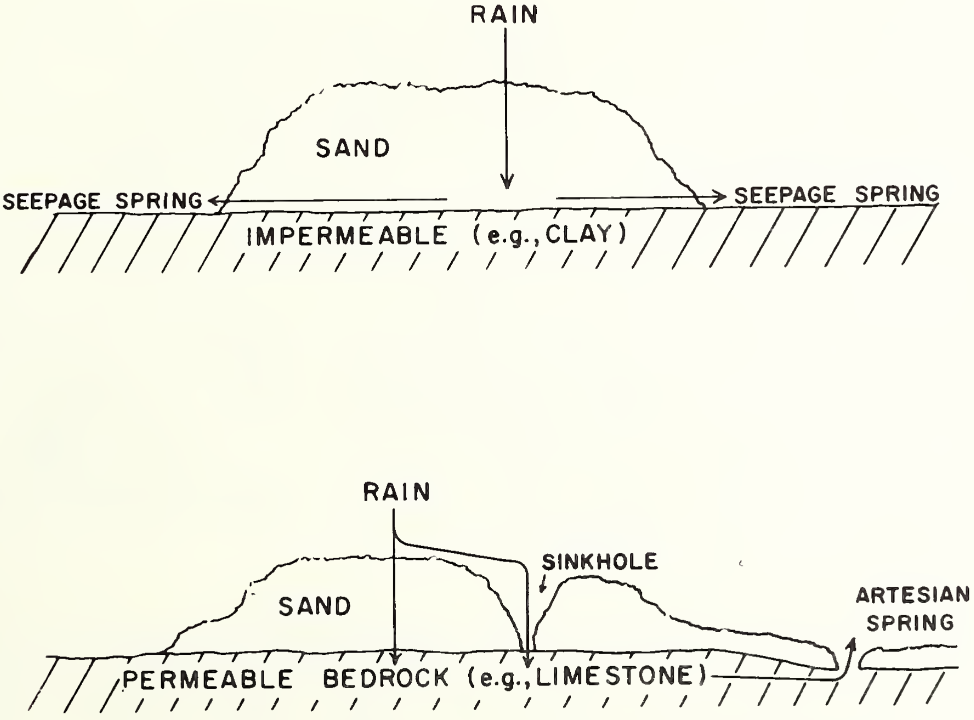


Figure 75.-Two types of springs based on source of water. Water flows underground over a horizontal impermeable material, such as clay, until it is exposed as a seepage spring. Artesian springs result when water percolates through a porous bedrock, such as limestone, and is forced to the surface at a lower elevation. The water which issues as artesian springs was maintained underground by aquicludes which are impermeable strata lying above and below the permeable stratum. (The vertical scale in these illustrations is purposely distorted.)

rainfall percolates down through the porous sands until it reaches an impermeable strata, for instance, clay. The flow is then horizontal to a point where the surface elevation drops to the impermeable strata level and the water issues forth as a seep or small spring Springs whose water issues vertically from a deep aquifer are called artesian springs. In this type, rainfall percolates into the porous limestone where it is confined under hydrostatic pressure. Sometimes the water may enter directly through sink holes. The hydrostatic head forces water from the aquifer at exposures at lower elevations, usually through caverns. Salt water springs resultswhen the fresh water is forced through the old sea bed (containing salt) of the Pliocene and Pleistocene when the sea covered this area (see Chapter IV). Juniper and Alexander are two well-known artesian springs (fresh water) and Silv Glen Springs is an artesian spring issuing from an old sea bed (salt water).

Spring waters are notably clear which allows sunlight to filter through to all expose surfaces. Except where the water flow is particularly swift, green plants may be observed on most of these exposures. Whereas these waters are exceptionally low in carbon dioxide and oxygen, there are adequate amounts of bicarbonate (HCO_3) and other minerals to maintai a viable community. The carbon for photosynthesis comes from the bicarbonate and dissolve oxygen which is evolved from the process (see Figure 9). The community assemblage is adapted to a relatively stable environment in terms of temperature, light, nutrients, water flow for remote wastes, etc. Differences among springs, however, with regard to these environmental factors, account for much of the variation one observes in the Ocala National Forest.

(2) Streams and creeks - Streams and creeks form the smaller channels which funnel seepage runoff and spring waters into the larger river channels or into bodies of water such as lakes and ponds. The terms are really expressions of size. As water percolates through o over the soil, which does not provide the almost perfect filtering ability of the aquifer, inorganic and organic materials are dissolved and carried into the surface waters. Runoff is the primary agent for this input contribution. This input is a source for nutrients st mulating photosynthesis and is a source of energy in the form of organic matter for aquati consumers. From your understanding of Chapter II, you will recognize both inputs as forms of auxiliary energy. Organic runoff and the increased abundance of water borne particles contribute to the color and turbidity of the water which serve to reduce light penetration Thus, there are relatively fewer photosynthetic organisms in proportion to the abundance o heterotropic forms. This is due to a high concentration of dissolved and particulate organic matter; energy sources for many small heterotrophs. The differences in the types of producers is reflected in the consumers. In the springs, production occurs in the attache plants and there are a lack of filter feeders such as small fresh water shrimps and molluscs who are adapted to filtering small organisms and particles from rich waters. To a large extent, this shift in photosynthetic components, from attached plants to phytoplankton, is typical of most dark or organic waters. Can you explain why muddy waters, rich in silt and clay, do not fit this discussion?

(3) Rivers - The largest channels of water flow are called rivers such as the Oklawaha and St. Johns surrounding most of the Ocala National Forest. Because of their larger size and direct access to the Atlantic Ocean, both contain marine organisms such as may be observed in the springs along the St. Johns River. Water flow channels of this size and topographical variation contain many kinds of aquatic communities. These are related to flow velocity, salinity, water depth, dissolved oxygen levels, substrate, and the organic-inorganic composition of the water. One particular type of community, the hydrophytic forest (swamp forest) is related to and maintained by seasonal fluctuations in water level.

Let's look more closely at each of these environmental influences. The rate of flow varies with the width and depth of the channel bed. Water flows are higher in the smaller beds and slower in the larger ones. Swift flowing waters scour the channel and keep it free of sediment buildups and most aquatic plants. Slow flowing waters such as are found in that wide part of the St. Johns River called Lake George, permit the buildup of bottom sediments and establishment of aquatic plant communities. Slow river flows leading to the sea also permit salt diffusion to occur and the high salinity of the St. Johns contribute to it being known as one of the largest inland estuaries. When the water is dark and deep, the flow velocity is low and there is little turbulent mixing of the water, the upper water

ually support aerobic (dependent on oxygen) communities and the bottom sediments support
naerobic (not dependent on oxygen) communities (see Figure 52 for a discussion of these
ocesses). If you discover any water body with these characteristics, lift up a sample
the bottom mud and smell it. The rotten-eggs odor is hydrogen sulfide, a product of an-
robic respiration, meaning that this particular community is functioning in the absence
oxygen. The substrate is also very important in determining who lives where; a rela-
onship you may find interesting to observe. Compare the species found on limestone, sand,
d and organic detrital sediments. Thick organic bottom sediments are usually anaerobic
d indicate that within the entire ecosystem, production has exceeded respiration for some
ason.

) Ponds and lakes - The previous discussion also applies to ponds and lakes through which
ere is a flow of water. There are many, however, in the Ocala National Forest that receive
ter but do not have an outlet in the form of a stream or river. Such water bodies are
mmon throughout the central forest area where water (runoff and seepage) collects in de-
essions of varying sizes in the ground. The depressions result from variations in topo-
aphic relief and from the cave-in of subterranean caverns (sink holes). Waters flow into
ese depressions and carry with them organic and inorganic materials. These materials are
corporated within the biomass of the communities or are quickly deposited in the bottom
diments. Water loss occurs through direct evaporation off the surface and through the
anspiration of rooted and floating plants. The result of this input of water and material
d output of only water, is the continual filling in of the depressions. This process is
lled aging and after a long period of time a pond becomes a marsh or a prairie and even-
ally land. The many priairies in the forest were once water bodies that have naturally
lled in. Obviously during the aging process the community components shift from those
aracteristic of a perpetually wet aquatic system to those adapted to the wet and dry fluc-
ations of a prairie. Even though prairies lack an abundant biomass and a complex struc-
re, like the swamp forest, they are extremely productive both in terms of gross photo-
nthesis and the abundance of wildlife.

) Impoundments and reservoirs - Throughout man's history he has continually expended ener-
es in removing, moving or storing water for some purpose. All of the ancient and great
draulic societies attest to the success of man's effort to manipulate water to his bene-
t. However, the fact that with the exception of several noteable examples, such as Hol-
nd, these societies are no longer around suggests that in the competition, nature has
oved to be the best water manager in terms of long-term survival. When water is impounded,
ch as in the Rodman Reservoir, the environment is altered and a community different from
e one displaced takes over. This process, as we have learned, is called succession. This
unlike our other examples in that the new community is quite different from the one dis-
aced because selection is for the species adapted to the physically altered environment.
e creation of the Rodman Reservoir changed the basin from a swift flowing river winding
rough a flood plain swamp forest to an inundated basin with an elevated, relatively stable,
ter level through which is cut a swath for the Cross-Florida Barge Canal. The new ecosys-
n which is developing in the basin reflects an altered environment which is selecting for:

(1) a higher ratio of water surface to swamp forest,
(2) more opportunistic successional species as opposed to specialist steady-state species,
(3) a larger role for anaerobic communities,
(4) detritivores and decomposers over food chain consumers, and,
(5) a simpler, probably less diverse, basin ecosystem.

the controversy over the canal and the Rodman Reservoir, arguments focused on species,
populations, on communities, on isolated and interacting environmental factors, needs,
sts, and personal recreation values. Possibly, one day in the future we will have per-
cted techniques not only to list the public service benefits of an ecosystem but also to
asure them and thus be able to rise above arguments based on tunnel vision, personal
terests and our changing values. Chapter VIII suggests a holistic (all factors considered)
d objective methodology for appraising the world around us.

Some species components of aquatic communities:

Because of the wide diversity in aquatic environments, the numbers of species which may be observed are enormous. In the Appendix, the fishes, for instance, may all be considered members of the various aquatic communities. Also, most animals drink water and to the extent they frequent these habitats, they too may be considered components. The plants are represented below and include just some of those species which are exclusively aquatic and which may be commonly observed.

Plant species:

Ceratophyllum demersum - Coontail. The species gets its name from the abundance of small leaves crowded around the main stems of the plant. The buds, and sometimes the foliage, are important food for wildlife especially wood ducks. The plant grows completely submerged and the thick foliage provides food and cover for small aquatic organisms such as shrimp.

Najas quadelupensis -Naiad.The naiad is frequently found growing beneath coontail a an aquatic understory species. During the hot summers, the coontail dies back and the naiad becomes the dominant species, providing food and cover for many organisms.

Hydrilla verticillata - Hydrilla or Asian Milfoil. The species, an exotic introduce from Asia, is now one of Florida's major aquatic weeds. It is extremely competitive in that it can displace most native species occurring in fresh to brackish (estuarine) water. It does not die back seasonally. Hydrilla growth may completely fill a water body such as a pond or stream to the extent that they become barriers to water flow and boats. The thickness is also so great that birds may be observed walking on the water, in reality, supported by the hydril just under the surface.

Nuphar advena - Spadderdock. This submerged aquatic plant with wrinkly leaves and thick stems is eaten by wildlife but is considered to be of poor nutritive valu The leaves are eaten by deer which cycle the minerals therein back to the terre trial communities.

Typha sp. - Cattails. Cattails may appear in almost any wet place and are often the first colonizers of a newly dug pond. The extensive underground stems spread s profusely that an acre stand of cattails may actually consist of a few plants. The Indians made a flour from the roots, ate the shoots as greens, and wove the leaves into baskets. Cattail marshes usually abound with small mammals.

Pontederia lanceolata - Pickerelweed. The bright bluish-lavender spikes of the pick weed can be found on the muddy shores of ponds, streams, swamps, and lakes. Ea flower lasts just one day as new ones open progressively below the growing tip the spike.

Saggitaria sp. - Arrowhead. Arrowhead is an emergent that makes good shade and shelter for young fish. Wildfowl eat many tubers and some nutlets.

Alternanthera philoxeroids - Alligatorweed. Alligatorweed is an introduced aquatic plant from South America that forms mats of hollow interwoven stems near the su face of the water. The stem may be unusally long extending 40 or 50 feet from the rooted portions near the shore. Alligatorweed is quite competitive, crowding out most other species that inhabit waters exceeding a depth of two feet. Lack of natural predation is one reason for widespread distribution of this aquatic plant.

Egeria densa - Brazillian Elodea. This aquatic plant was introduced from Brazil and has spread rapidly through Florida's fresh water. Elodea is a popular aquarium plant because it grows rapidly thus producing a large amount of oxygen for the consumers. Unlike in natural communities, the excess production can be removed this perpetuating its benefits in an aquarium.

Pistia stratiotes - Water Lettuce. Water lettuce is a floating rossette of leaves the frequently covers the entire surface of ponds or bodies of slowly moving water. Stranded plants can be found on muddy shores where like the water hyacinth they may persist onthe moist earth for a period of time. Note that hyacinths and water lettuce are seldom seen to be abundant together on the same body of water. Water lettuce flourishes best in limestone waters.

Azola caroliniana - Water Velvet. Water velvet, a small fern, floats on the water, often giving the whole surface a red-velvety coloring when seen from a distance. This species is an important food for aquatic birds.

Lemna minor - Duckweed. This very small (only a quarter of an inch long) plant, usually consisting of a leaf or two and a few slender roots, can quickly cover a small still water body in one season. Wind, however, will break up the mats and pile them up along the downwind shoreline. When placed in water with a bad smell, the duckweed will eventually eliminate the odor. While you are camping, place a single individual plant in a glass of water and see how long it takes to multiply and cover the surface.

Salvinia rotundifolia - Floating Moss. Salvinia is an aquatic fern that has tiny surfaces and submersed leaves that give the appearance of roots, but this plant has no true roots. If you have an aquarium, you are probably already familiar with Salvinia.

Scirpus californicus - Bullrush. The Indians ate bullrush stems and boiled the seeds to make cereal. The foliage and stems of the bullrush were used in basketry. Bullrush is common along shallow water shorelines.

Bacopa spp. - Water Hyssop. A sprawling, fleshy herb that lives along wet river banks.

Vallisneria americana - Wild Celery. The ribbonlike leaves that float near the surface of the water are attached to stems that are buried in the bottom mud.

Cicuta spp. - Water Hemlock. Grows in marshes and along streams. Swollen and fleshy roots have attractive odor, but are very poisonous. Fruit is round with flat corky ribs.

uatic animals

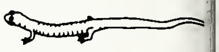
The forest visitor often is attracted to the aquatic communities to observe nature's dis-
ay of wildlife. For maximum enjoyment, take along your field guide, select a quite spot
erlooking a body of water and quietly observe the action. You will see things you ordi-
rily would have missed by creating a disturbance or by trying to see too much too quickly;
tures does not perform for the impatient. To see some animals, however, will require skill-
l participation on your part to carefully expose their hiding places. The following des-
ibes some of the animals you will enjoy observing.

e Mole Salamander (family Ambystomidae). The members of this family may be found in many terrestrial communities, but always in the wettest areas among the damp litter on the forest floor or in the swamp forests. They are all burrowers but are active (at night) on the soil surface particularly during the breeding season and may be observed by carefully pulling apart the organic material in wet areas. The rare tiger salamander burrows in the drier habitats of the Forest. The mole salamanders make excellent pets in a well-kept terrarium.

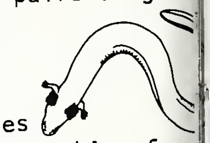
e Amphiuma (family Amphiuma). There is a single species, Amphiuma means the two-toed amphiuma, which may be observed in the Forest. Two-toed amphiuma are eel-like with extremely small, useless-looking limbs; eyes are dot-like and without lids; often cannibalistic; commonly found around pools, swamps and prairies near wood debris; recognized for their size (2 to 3' in length), presence of gill slits and two toes; relatively abundant. Be careful, though, these creatures inflict a terrible bite.

The Newts (family Salamandridae). The newts are not as slippery as the majority of the salamanders and are capable of producing a toxic secretion to discourage predators. The striped newt adults inhabit shallow ponds and wet prairies in the flatwoods and also occur in the hydrophytic hammock. The common newt may be observed in areas of standing water.

The Lungless Salamanders (family Plethontidae). As you might have guessed, these salamanders have no lungs; oxygen intake and carbon dioxide release occurs through the skin and mouth lining. This family is also unusual in that the lower jaw is immovable, thus, an individual must lift its upper jaw and head to encompass a food item. Four lungless salamander species occur in the Ocala Nation Forest: the dusky, the slimy, the mud and the dwarf salamanders. The mud salamander occurs in wet areas but is considered to be rare. The dwarf salamander is the smalle of the salamanders and unlike the others, has four toes on its hindfeet rather than five.



The Sirens (family Sirenidae). The sirents are all aquatic and retain three pairs of gill throughout life. They are eel-like with one pair of limbs (front) and small lidless eyes. Three species may be commonly found in the aquatic communities of the Ocala National Forest. These are:



Siren intermedia - Dwarf Siren or Lesser Siren. Common in ponds, ditches and swampy areas, particularly in the flatwoods and cypress domes; capable of su viving droughts by burrowing in the sediments to await the rains.

Siren lacertina - Great Siren or Greater Siren. Large, up to 20 to 30" in length; found in perpetually wet areas particularly around the roots of water hyacinths. Look for both the great siren and the mud siren among the water hyacinths in the water bodies of the Ocala National Forest. The sirens are the only group of ver tebrates to have benefited from the introduction of this water "weed".

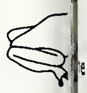
Pseudobranchus striatus - Mud Siren. Smallest of the sirens; common among floating vegetation such as the hyacinth.

The Toads and Frogs. The hindfeet of the spadefoot toads (family Pelobatidae) are adapte for burrowing in loose sand. They breed, however, in rain pools created in terrestrial communities. The family representative in the Forest is the eastern spadefoot toad.

The true toads (family Butonidae) are distinguished from the spadefoot by their warty looking skin which gives them a "true" toad-like appearance. The skin of the true toads secretes an irritating mucus which is effective in repelling predators.

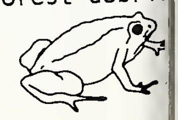
The greenhouse frogs of the family Leptodactylidae are an exotic introduced species are unusual in that they lay their eggs in terrestrial rather than aquatic communiti The tadpoles become adults within the eggs rather than as free-swimming organisms. size of the greenhouse frogs is about one inch.

The tree frogs, in contrast, lay their eggs in water which hatch into tadpoles and t metamorphose into adults. They are small, long-legged frogs, many of which are noted for the adhesive discs on their toes. The species of the tree frog family (Hylidae) are represented in many communities of the Ocala National Forest.

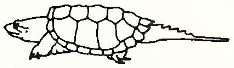


The common frogs (family Ranidae) are narrow-waisted, have smooth skins and the fing are free but the toes are webbed. Members of the Ranidae are harvested for commercial frog legs.

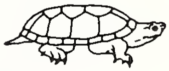
The eastern narrow-mouth toad (family Microhylidae) is a single species representative in the Ocala National Forest. They breed during the heavy rains between April and October. Look for this species under logs and forest debri



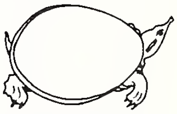
he Turtles. Of the many turtles which you may observe, three families are of particular interest because of unusual characteristics. The snapping turtles (family Chelydridae) are harmless, but may become dangerously aggressive when molested or cornered. The snapping turtle (shown at right) on land may actually rise up on his hind legs and lunge forward. The alligator snapping turtle grows to a very large size and is the largest of the fresh water turtles. All turtles breathe air and the best way to see an elusive turtle is to wait patiently for it to surface, sticking its head up to breathe.



The stinkpot turtle belongs to the family Kinosternidae and is known both for his ability to climb and his musky odor. The stinkpot may be seen on the highest logs and will clumsily fall when disturbed. The odor comes from two glandular openings on either side of the body from which exudes a musky secretion.



The softshell turtle is distinctive because of its soft plastron (shell). The softshell turtle is a strong swimmer and is unturtle-like in his agility on land. When looking for turtles sticking their heads up above the water, look closely; it may actually be the nostrils and eyes of a cruising alligator.



e Gar Fish (family Lepisosteidae). The gars (Lepisosteidae, meaning bony scale) are long-cylinder fish, with hard scales and elongated mouths. Their carnivorous appetite for game fish and their ability to thrive in eutrophicated water bodies have given them a reputation as a trash fish. The large gars cruising near the surface of the water provide a target for bow hunters whose arrows are tied to stout lines. This sport was once encouraged in Florida to help "control" population sizes of gar.

e Shad and Herrings (family Clupeidae). The Clupediae contain the shad, menhaden and herrings. These fish are not game fish, but are important commercially for the fish meal, fertilizer and pet food industries. The gizzard shad and the threadfin shad are abundant in nutrient-rich lakes and waterways and are species which are indicative of poor water quality. Shad are very prolific in that 20,000 - 30,000 eggs may be produced at one time, with high survival.

e Pikes (family Esocidae). Whereas the pike and muskellunge do not occur in Florida, two other members of the family Esocidae, the chain pickerel and the redfin pickerel occur in Florida and in the Forest. They are predaceous much like the gars and have been known to eat birds and snakes. Although any top carnivore is a game species to man, the pickerel's more northern cousins are the more highly sought after. The chain pickerel thrives well in impoundments such as the Rodman Reservoir.

e True Minnows and Carps (family Cyprinidae). The cyprinidons comprise the largest family of fish with many species represented in the Ocala National Forest. The term minnow is usually used for any small fish, particularly juveniles. Thus the adjective "true" indicates that this is a distinct group of normally small-sized (several inches long)fish. The cyprinidons are basically omnivorous, feeding on both plant and animal material. Many, such as the carp, are scavengers and none have teeth. All species do, however, have teeth in their throats. Their small size and abundance make this group an important food resource for predaceous fish. The live bait fish you buy such as the shinner, will be a cyprinidon.

e Catfish (family Ictaluridae). The catfish are touch and taste scavengers and thus are able to be active at night, in turbid (dark) waters, or in underground streams such as Florida's limestone basement. In spite of their questionable dietaries, catfish are valued as a tasty dish. Commercial catfish, however, are raised in ponds where they are fed a specially prepared ration. The family name is derived from the Greek words for cat and fish.

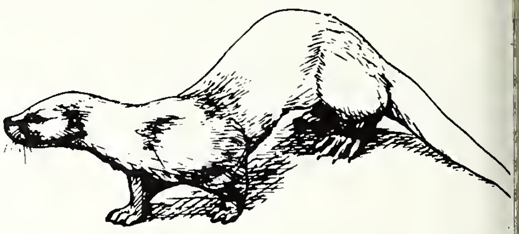
e Live Bearers (family Poeciliidae). Unlike the other fish which lay eggs, this family consists of species which give live birth. This unusual aspect, together with their small size and diverse color and shape, makes many of this group appealing as aquarium fish. The mosquito fish (Gambusia affinis) is a carnivore which preys on mosquito larvae; thus its name. Also in this family is the smallest fish in North America, the least killifish (Heterandria formosa) with a maximum size of 1". Both occur in Ocala.

The Darters or Perches (family Percidae). This family is composed of fish species with no air bladder which is an internal mechanism for stabilizing bouancy. Being heavier than water (i.e. they do not float), they rest on the bottom supported by their fins. The Percidae are all carnivorous and are regarded as both food and game fish. These small fish occur extensively throughout the Forest.

The Sun Fish (family Centrarchidae). The distinguishing characteristic of this family is the presence of three or more spines in the anal fin. To the fisherman, they are distinguished , however by the fact that all are game or pan fish and include the bass, crappie, warmouth, bluegill, shellcracker and pumpkin seed. There are also species such as the banded pigmy sunfish in the Forest swamps which are too small to be a gam fish or a candidate for the fry pan. The largemouth bass is the largest freshwater game fish in Florida and one for which fisherman will travel a thousand miles to catc

As you explore the aquatic communities of the Ocala National Forest you may come acro a worn place in the bank which looks like something has slid down it many times. This may a slide of the elusive but playful river otters. The otters belong to the family Mustelid (fur bearers) and are an aquatic mammal. The otters' rich brown coat, thick tail and webb feet with hairy soles distinguish them from other mammals. They are carnivores, weighing 6-20 lbs, and have no enemies except man. Their diet consists mostly of fish and amphibia but it also includes ducks, snakes, and crayfish. They usually travel in pairs and may mo overland several miles to a different body of water.

RIVER OTTER



Also as you explore these communities, you will see many snakes, many of which you may believe to be the cottonmouth water moccasin (Agkistrodon piscivorus), but are proba the harmless water snakes (Natrix spp.). However, because the moccasin is so dangerous, is probably best to leave these snakes alone unless you are positive of the correct ident fication. The common name for the cottonmouth is self-defined; the open mouth has a whit cotton-like appearance. The species name, piscivorus (from the Latin pisces, meaning fis refers to the moccasin's diet which includes fish as well as other aquatic animals.

Remember, the worst pest in the Ocala National Forest is the domestic litter bug.

CHAPTER VII

INTERACTIONS BETWEEN SPECIES

The term "symbiosis" literally means "living together" in some sort of association or in some expression of an interrelationship. Thus, it aptly describes all of the relationships among the living components of any ecosystem, in that the particular assemblage imparts to that system its characteristic structure and function. The two previous chapters have described the biotic compartment of the various Ocala National Forest ecosystems in terms of communities and individual species. Mere descriptions, however, offer little insight into understanding how a particular assemblage of species interacts to form the community system and contributes to the maintenance of its integrity. Prior to fully understanding the structure and function of an ecosystem as a community of interacting species, one must first understand the types of interactions which species may exhibit. These types may be considered as smaller sub-systems within larger systems and may exhibit numerous variations. Recognize, however, that the forms of symbiosis are learned in the field only through many hours of careful observation.

Traditionally, the possible numbers of types of interactions between any two species has been limited to eight, based on whether the result is beneficial, harmful or of no onsequence to either of the two interacting species. Except under rather well-defined ircumstances, the base types are the exception rather than the rule because any single pecies may interact with other species in many different ways depending on the constantly hanging conditions in any ecosystem. For the most part, everyone will intuitively recognize ach of the types and will also tend to subjectively evaluate them according to whether the nteraction result is "good" or "bad" for the species population in question. There is, owever, no "good" or "bad" interactions in nature, for each contributes to the overall aintenance of the ecosystem and, hence, its survival. As discussed earlier in Chapter II, eing competitive and therefore surviving is dependent upon maximizing the flow of energy hrough a system.

This duality of viewpoints, i.e., toward the species or toward the system of which he species is but one component, is a critical but obscure issue in the management of cosystems. Management practices which minimize the "harmful" interactions and maximize he "beneficial" interactions relative to a species, will alter the structure and function f the parent ecosystem. There are numerous instances where management for the benefit f a component species has altered ecosystems beyond tolerable limits. Predator control, or instance, to "protect" domestic animals invaribly leads to increasing populations of rey, the damage from whom often exceeds the value of the animals protected. Similarly, ccessive management in favor of a species, such as deer has led to populations whose size efeats the purpose of the "management" effort. The effects of such management pitfalls ould be examined before a decision is every made concerning the management strategy to followed. Nevertheless, it *is* important to understand how any two species may interact any given time.

If the interactions between any two species are considered as being beneficial, rmful or of no consequence to either of the two, then it is obvious that there are x basic types: competition, amensalism, parasitism, mutualism, commensalism and utralism. Two of these, however, mutualism and parasitism, are usually subdivided into otocooperation and predation, respectively. These relationships were derived by ecogists who were interested in studying sub-systems of two species under relatively conolled conditions. By adhering to these conditions it is possible to assign positive and gative effects to population interactions because these systems are very simple and have e tendency to oscillate. In a natural ecosystem, however, we interpret population interlationships on a different scale. In the ecosystem the population has roles which are portant to itself and the whole community of organisms. Since populations do not exist a vacuum but within the framework of the ecosystem, it is to the benefit of both the osystem and the population for it to be in "optimal health". By optimal health we mean at the population be composed of healthy individuals with a normal age distribution, not o many or too few organisms, and with the right proportion of males to females and juveniles to adults to insure stability between the birth and death rates. A balanced, or stable, population is in the best position to fulfill its role in the system with the highest possible efficiency. Thus, both the system and population benefit.

To achieve such ideal population compositions, ecosystems depend on the varied network of population interactions. These interactions are, in reality, the mechanisms controlling the flow of energy through the populations in the system. Each population recei an amount of energy with which to do its ecological work in the system. Since the result of all population interactions is that energy flow is maximized through the participating populations, and since this is consistent with the "objective" of the ecosystem (to maximize energy flow) it is then of questionable meaning to assign (+) or (-) values to interactions. They all contribute to the survival of the best adapted ecosystem to the local environmental conditions. In the following discussion we show how seemingly negative interactions such as predation, are in reality desirable for the maintenance of a healthy ecosystem.

Neutralism or Independence

Neutralism is the expression of independence between two contact species. Even though the two species may occupy the same geographical habitat, their specific niche requirements are sufficiently different to prevent one species from having any direct effect on the other. Because, however, their common resource is the ecosystem which supports them, any alteration of the energy flows or mineral cycles may cause corresponding effects, detrimental or beneficial, on either or both of the two species of interest. A typical example is depicted in figure 76. Here the white tail deer and a hawk are show to be occupying the same habitat at the same time. Their niche requirements, and specifically their dietaries, are so different however, that neither species population has an effect on the other.

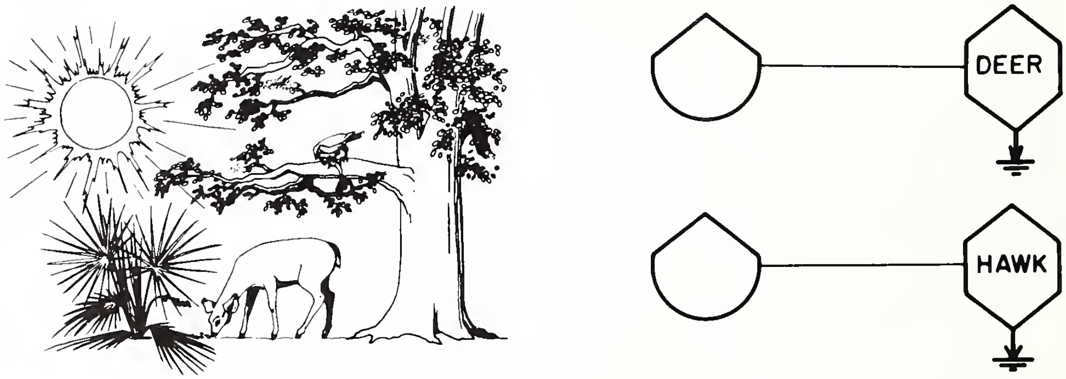


Figure 76.-Neutralism or independence. Deer and hawks are common components of the same ecosystem. The deer is a browser feeding on plant materials; in this illustration on the fruits of the palmetto. The hawk is a raptorial bird who feeds on small vertebrate prey. In this instance each is performing its role in the ecosystem with no direct effect on the other. Expressed in terms of energetics, the food resources and consumers are independent.

ompetition

Competition occurs between two or more species when a portion of their niche requirements overlap and no alternatives are available. Both deer and feral (wild) hogs include n their diets acorns and a variety of herbaceous plants (figure 77). Under normal circumstances, these items and the other respective dietary items are present in sufficient mount that deer and hogs are not forced to compete for the same finite food resources. n the event food was limited, both, however, may enter into direct competition. In the xample, both the hog and the deer are competing for the same limited food resource and re, in effect, diminishing the flow of energy into the competitor through the increased ork of searching for food. In reality, though the stress may become severe, competitive xclusion probably would not occur as each would begin to exploit less desirable food tuffs which may be unavailable, or unpalatable, to the competitor. Hogs, as noted in the llustrated example, serve as cultivators in their search for food. They turn and churn e soil and actually serve to stimulate herbaceous plant production. Thus, after competition has subsided the new growth would provide abundant food to restablish the deer opulation.

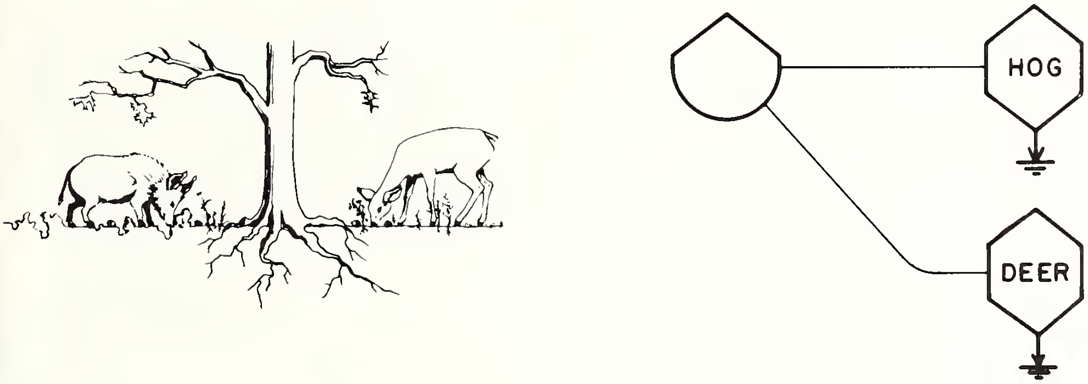


Figure 77.-Competition for a limited resource. Whereas deer and feral hogs do not usually compete with one another for the same food items, occasionally heavy population pressure and/or a decrease in total food items will force them to compete for the same foods. Under the extreme circumstance illustrated here, hogs will out-compete deer because hogs are more efficient in that they are less selective in what they eat. The deer is more selective. The energy diagram represents the initial conditions in competition.

The concept of competition is sometimes confused with other types of ecosystem interations, such as when one species disappears and another increases in population size as ccurs during succession. Maybe the role one species was performing was no longer needed ad a new role was created for which that species was not adapted. Such observed phenomnon are sometimes more complex than can be explained on the basis of a simple competitive iteraction. In moving through a grocery check-out line are you competing with anyone for te cashier's services or are you just waiting your turn?

Another expression of competition involves the competition among members of a trophic lvel for the opportunity to be eaten by a predator in a higher trophic level. The predtor-prey interaction is one of the simplest methods of population size control both for te prey and predator. The ability for a species population to avoid becoming too large i as important as avoiding a drastic decrease; neither contributes to the continued survival of the species. Thus, when populations become too large, benefits accrue to the population by reducing its overall number. Assume that bobcats are the sole predator for both squirrels and rabbits whose population size are momentarily too large. Bobcat predation thus would benefit the species which could be eaten in the greatest number (figure 78).

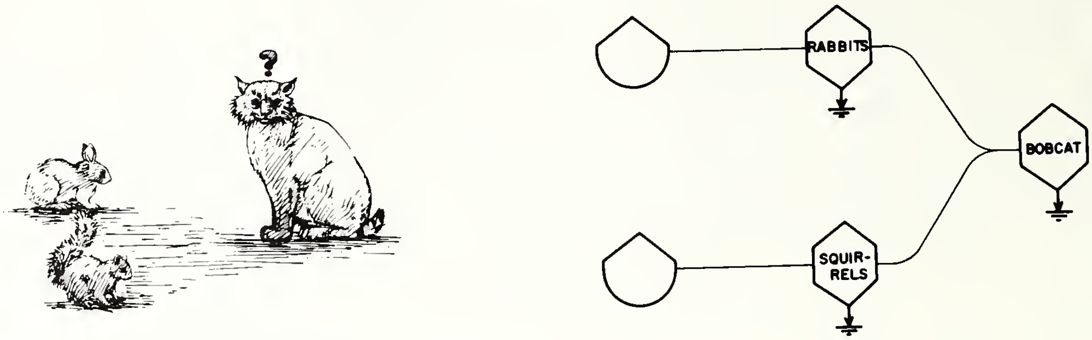


Figure 78.-Competition for the population control services of a predator. In this example, the populations of both rabbits and squirrels are too large and may run the risk of starvation, disease, reduced fecundity, etc. If, however, a predator such as the bobcat were to reduce a species population size, the action would benefit that species. In nature, the predator feeds on the population whose numbers are greater and therefore easier to find; a built-in control to prevent over population.

Another example (figure 79), which shows what appears to be competition but is really in effect beneficial, is the relationship among squirrels, quail, and jays in th Ocala National Forest. They all feed on nuts and acorns and thus seem to be in competition. However, the squirrels and jays take their nuts and acorns to a tree branch and while feeding drop a portion of their take. The quail, which feed on the ground, take advantage of this supply of food which is thus ready to eat since the squirrel and jays have already stripped the fruit of its hard shell. Squirrels and jays therefore encour competition!

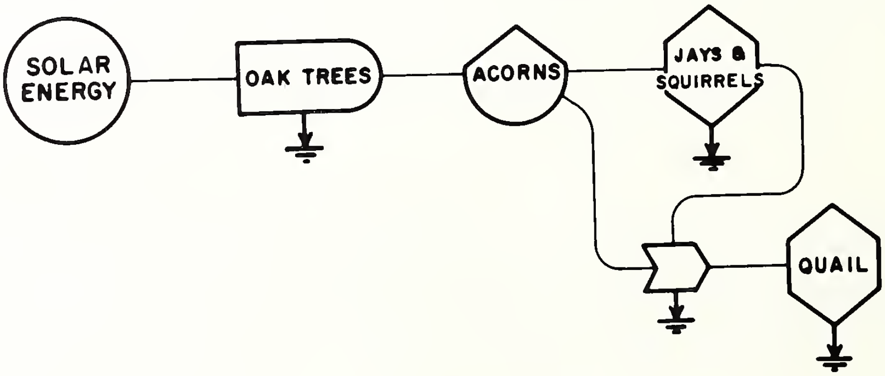


Figure 79.-Competitors encouraging competition. Squirrel, jays and quail all feed to some extent on acorns although quail have a difficult time opening the seed. However, if the squirrels and jays first break the seed coat, then quail can readily consume the acorn. In the diagram, the drain on the acorn stock is proportional to the number of acorns which are broken open but dropped by jays and squirrels.

Predation and Parisitism

We have already described how two species may "compete" to be eaten and when one organism eats another, the interaction is called predation. The predator eats the prey (figure 80). Since predators usually have a variety of foods, they tend to eat those which are most abundant or are the easiest to catch. In so doing, they control both the numbers of the most abundant prey and its fitness by eating the slow, sick, or the careless. Predators in turn are controlled by the availability of energy to their trophic level. Since they are far from the level of the photosynthetic fixation of energy, predators must spend a great deal of time searching for prey and concentration energy (see figure 24).

The action of predators far up the food chain have effects on trophic levels close to the plant producer. For example, in the Ocala National Forest cotton rats are the main predators of quail which in turn feed on plant parts. The marsh hawk however, controls the quail population by feeding heavily on cotton rats. In so doing they reduce the main predator of quail.

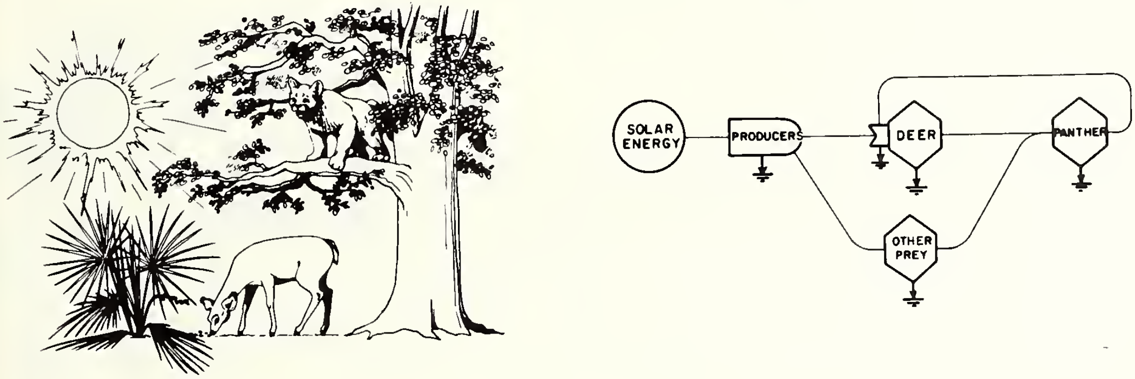


Figure 80.-Predation. The Florida panther is a predator who includes deer among other prey in his diet. The sequence represents a trophic transfer of energy which is diagrammed to show the benefits of population control on the deer herd.

Another population control mechnism which has an effect on predation rate is parasitism (figure 81). In parasitism one or more organisms (the parasite) feeds upon, or secures shelter, on one or more other organisms (the host). Parasites may live internally (endoparasites) or externally (ectoparasites). Many organisms like the squirrel have parasites during some specific period of the year without any apparent harmful or positive effects on the host individual. But they may, in addition, also have parasites which reduce the "vigor" of the individual to the extent that he becomes suceptible to predation or some lethal disease. Parasitism, competition, and predation are usually most intense and thus serve as population control factors when the density or organisms increases to a certain high point. For this reason, these interrelationships are termed density-dependent; their interactions being in proportion to the density of organisms. In contrast, density-independent factors act independently of population density. A fire may occur whether there are 1 or 1,000 deer in an area.

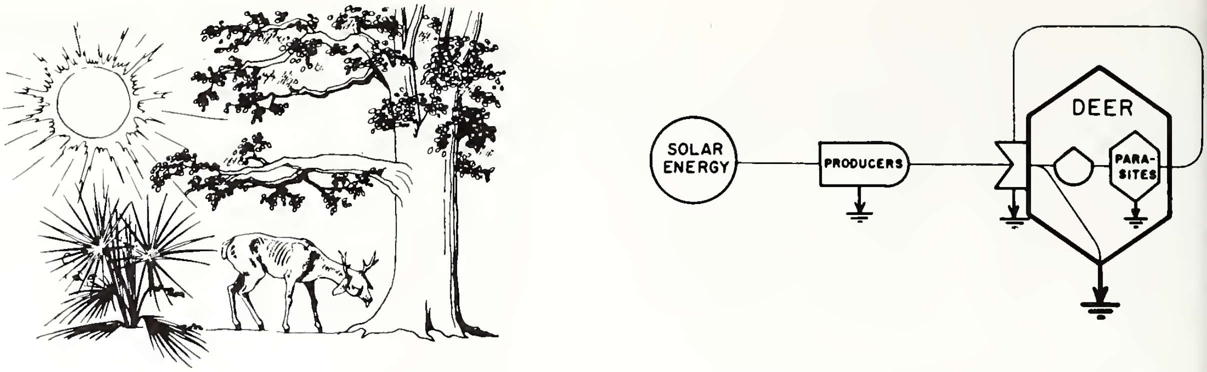


Figure 81.-Parisitism and disease. Without predators to control population size, other control agents such as parasites and disease become established, in many instances, in epidemic proportions. We might say that predators not only control population size but also the overall health of the population. In the diagram, the parasites are shown tapping the energy resources within the host and by reducing the vigor of the host, the total energy flow is reduced.

Mutualism

Lichens are very abundant in the Ocala National Forest covering as much as 25-30% of the forest floor in many areas. The lichen (figure 82) is an symbiotic association between an algae and a fungus, each depending on the other for survival. The algae produces energy-rich compounds through photosynthesis and the fungus provides shelter and minerals for photosynthesizing algae. Thus, the relationship is one of mutual benefi Scientists, however, have been unable to separate and grow lichen components in isolation as each is wholly dependent on the other. In a lichen we find all the main attributes (production, respiration, cycling, structure, coupling, etc.) of a large ecosystem encapsulated in a small miniaturized model; a microcosm. They are very abundant in the sandpine and in some sandhill areas. Look for them.

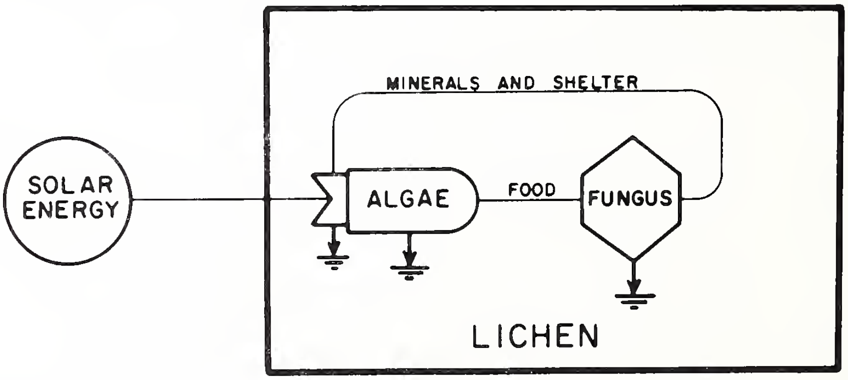


Figure 82.-Mutualism in a lichen. A lichen is composed of a species of photosynthetic algae and a species of fungus. Different lichens have different algal and fungal components. The algae converts solar energy into chemical energy which is used to sustain both the algae and the fungus, i.e., the lichen. The fungus provides the structure within which the algae lives and in the process of respiration breaks down the energy-rich organic materials and recycles the minerals back to the algae for re-use in photosynthesis. Neither the algae or the fungus in a lichen can survive without the other; mutualism.

rotocooperation

Whereas in a mutualistic relationship each species is dependent on the other, there re many examples of species mutually benefiting one another, but neither of whom is wholly ependent on the other. This non-obligatory form of mutualism is called protocooperation.

Squirrels, oak trees, and acorns are common components of the American landscape and he Ocala National Forest has a visible share of these ecosystem components. Acorns serve s a basic food for many game species in the forest and the oak trees, which produce the corns, serve as nesting sites for many birds and game mammals. The squirrel is one of he organisms that feed on acorns and also nests in older oak trees (about 30 years and lder). Through evolutionary time, however, squirrels and oaks have evolved together, ach one leaving his impact on the other. While acorns are reproductive structures of aks, they also feed squirrels which in turn provide a dual service to the oaks; (1) They lant acorns in the ground and thus benefit the oak in its regeneration and (2) they exert n evolutionary pressure on the reproductive structure and thus control the evolution of he seed. Both populations benefit from the relationship and probably both would survive ithout it (figure 83).

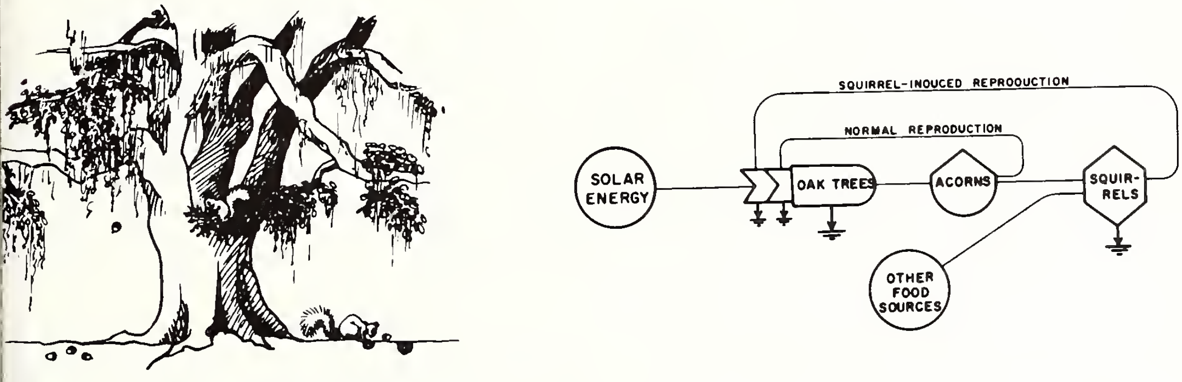


Figure 83.-Protocooperation between squirrels and oak trees. As shown in the diagram, energy flow into a population of oak trees dependent upon the oak's ability to continually re-establish itself through reproduction. Squirrels, however, assist in this process by burying acorns for subsequent retrieval. Those acorns not retrieved and eaten, remain protected from other consumers. Germination of the seed established a new member of the oak tree population. Neither oaks or squirrles are dependent on one another as are the components of the lichen. Each can survive without the other.

ommensalism and Amensalism

Among the asemblages of organisms in any ecosystem, there are components whose ere presence causes benefits or detriments to accrue to other components. Unlike mutualsm and protocooperation, however, which describe effects on both interacting species, hese two forms, commensalism and amensalism, describe an effect on only one of the two nteracting species. In a commensal relationship one species has a positive effect on he other while in ~~an~~ amensal relationship the effect is negative. These two contrasting nteractions are diagrammed in figure 84.

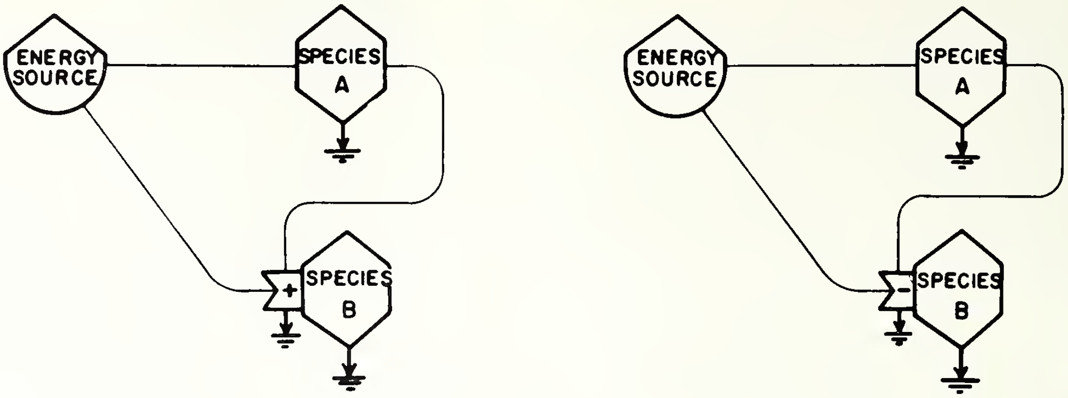


Figure 84.-Commensalism and amensalism. In a commensal relationship, species B derives a positive benefit from the presence or activity of species A. In amensalism, the one-way relationship is negative.

One may observe many expressions of commensalism and amensalism through careful observation. Commensal relationships, for instance, exist between the mossy-back turtl and the attached algae, the organisms associated with the water in pitcher plants and various bromeliads (air plants), and many insects which one may observe to be associate with a single plant species. Van Beneden (1876) described a commensal organisms as a messmate who "requires from his neighbor a simple place upon his vessel and does not partake of his provisions." The relationship may range from being one of dependent obligation to one of non-obligatory convenience.

As stated, amensalism is the reverse of commensalism in that Van Beneden's messmat interferes with the well being of his host. The relationship, however, is not confined just to this host-intruder type of interaction but includes such interactions as one species interfering with a competitor. For example, during the process of decompositio of forest floor litter, many species of small invertebrates, bacteria, fungi, etc., "tal turns" in the process. When one species, or group of species, is dominating the proces their competitors are inhibited (figure 85). Bacteria, for instance, produce antibioti

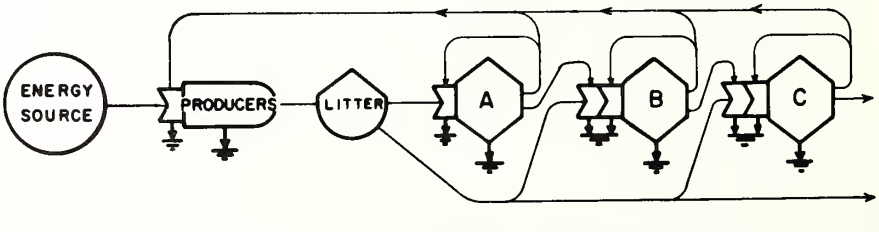


Figure 85.-Amensal relationships in the succession of decomposers of forest floor litter. In the sequence, species A is the first organism to begin processing litter and in doing so discourages occupation by species B. As A completes its specialized role, its flow of energy is stopped and B's role becomes dominant. B's relationship to species C is the same as expressed between A and B. As decomposition proceeds, the sequence is repeated until all litter has been decomposed or until new litter is added which re-initiates the sequence.

which inhibit competing bacterial population. As the decomposition process proceeds, each group consumes its specific food resource in the litter, thus allowing occupation by other species specialized to feed on some portion of the remaining litter.

As the reader has probably observed, all of these symbiotic interactions are based on the interpretation of the phenomenon of interest. In figure 86, fire is illustrated as a competitor with all other organisms for the forest floor litter. Because fire is able to command the greatest energy flow, all competing species in the litter are eliminated through competitive exclusion. As a new system regenerates, however, the excluded organisms eventually become re-established.

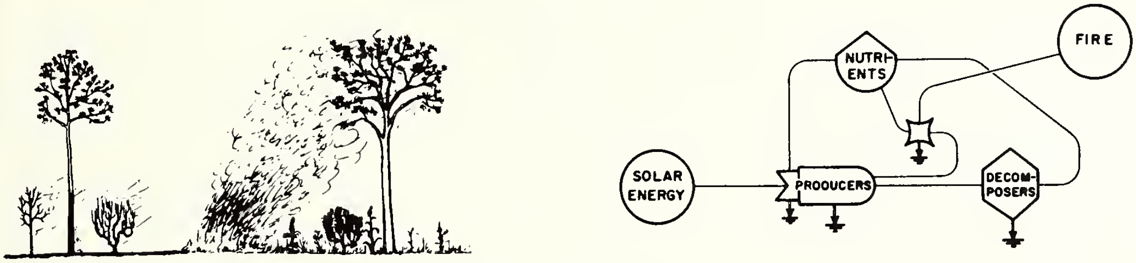


Figure 86.-Fire in an amensal relationship with other consumers of forest floor litter. Litter is a product of photosynthesis and is thus composed of carbon, hydrogen, oxygen and the mineral nutrients. Consumers, through the process of respiration, oxidize this organic material into carbon dioxide, water and the constitutent minerals. Fire similarly oxidizes organic materials but at an incredibly faster rate. If we consider organic matter as an energy resource for any oxidation process, then fire is a competitor in an amensal relationship with animal consumers. In this example of fire, competitive exclusion of forest floor organisms is virtually the rule.

CHAPTER VIII

THE ECOSYSTEMS OF THE OCALA NATIONAL FOREST

INTRODUCTION

"The scrub is most interesting and weird. The vegetation is mostly dwarfed, gnarled and crooked, and presents a tangled straggley aspect. It appears to desire to display the result of the misery through which it has passed and is passing in its solution of life's grim riddle. Here lives rosemary (*Ceratiola ericoides*), spruce pine [sic] (*Pinus clausa*), poor grub (*Xolisma ferruginea*), and their associates rooted in a bed of silica, to which the term soil is but remotely applicable. Here the sun sheds its glare and takes its tol of the unfit."

The above description of the scrub community was given by Mulvania in 1931. Vividly, he captured the environmental and biological features of the area which together interact to form what we recognize as an ecological community or in our language, the ecosystem. Th vast majority of the Ocala National Forest is dominated by this fascinating community know as the Big Scrub. The Big Scrub is in turn maintained by an array of organisms, each with fascinating adaptations suitable for the local environment. In our efforts to understand the detail of the Big Scrub we tend to forget that beyond the individual adaptations are the interrelationships of individuals and factors which are the key elements that form the ecological community. In such units of biological organization, single components (specie litter, soil, etc.) are intercoupled and never is one of them isolated from the rest. An isolated component, by definition, is not part of the ecosystem. Therefore, the unifying feature of the ecological community is the interaction of its parts, each part contributin to the success of the whole. The structure that we observe becomes the net result of all the interactions between the community members which contribute to the overall success and thus to the survival of the integrated system.

The Niche and the Habitat

We now ask: How do organisms (both plant and animal) allocate space and resources am themselves so that their interactions result in a cohesive functional community? The answ to this question lies, of course, in the evolutionary history of the community itself and its energy flow patterns, but two ecological concepts will help us to visualize how this i done. For assistance let's refer to the concept of niche and habitat. The niche is defin by the role of an organism in a community, and its activities and relationships with other organisms and with its physical environment. The habitat is defined as the sum total of tl environmental conditions of the specific area occupied by an organism, population of organisms, or community of various populations. These concepts mean that all species in nature have a range of conditions over a geographical location that constitutes their home range o habitat. Seldom would they be discovered outside of this range, for their activities are restricted to the particular habitat which supports them. Within their habitat, all speci have a function, role, or niche, which represents what the species do in the environment (both physical and biological). For example, deer are found in the Ocala National Forest, mostly in the scrub, flatwoods, and hammocks. These communities represent the deer's habitat in the Ocala National Forest. As they move from community to community, deer eat plan parts (leaves, twigs, acorns, mushrooms, etc.), they trample vegetation, deposit their was are eaten by feral dogs, compete with bear and hogs, etc. These are the functions that de perform in their habitat and thus represent part of the deer's niche. We can evaluate the impact of deer in the forest by describing their niche.

It is probably obvious to the alert reader that a strong analogy of niche and habitat exists in our own social organization. In our society, our habitat is our address and the various places that we visit as part of our daily routine. Our niche is the work that we perform in the community, including our roles as family members, citizens, and workers. This activity that creates an impact on the behavior of our overall social system or local community is but one of the many analogies between social and natural systems. In fact, all systems, regardless of their level of organization (microscopic or macroscopic) or composition (inert or living), have similar properties which can be described by similar laws and principles. The field of general systems theory deals with these properties, of whic biological systems and social systems are examples.

ommunity Interactions

The vegetation cover has a large effect on the diversity and characteristics of habitats within a community. The Ocala National Forest has a similar climate throughout (figure 65), but it is composed of a mosaic of community types of varying diversities and environmental conditions. On one end of the spectrum are the relatively open areas of scrub and sandhill communities with low diversities, high temperatures and large variations in temperature, low humidities and intense solar radiation penetrating into the community. Hammocks and swamps represent the other extreme with very low light penetration through the canopy, lower temperatures and diurnal or seasonal variations, and higher humidities, and a diversity of organisms. Intermediate between these extremes are the pine flatwoods and other communities scattered throughout the Ocala National Forest. These modifications of conditions by plants are in turn regulated by the capacity of plants to negotiate differences n soils and topography, and by the historical accidents of the area itself. The modification of the physical environment is one of the roles or part of the niche of the plant species within the ecological community. The concentration of potential energy through photosynthesis is another vital part of the plant's niche.

Animal species and plant species are programmed to function within the range of conditions resulting from the modification of climate by the plant cover. For example, certain oak seedlings survive only under the deep shade of the hammock community. Sand pine, however, rows best after a fire, under intensive light and fluctuating temperature conditions. imilarly, burrowing organisms are programmed for survival in open communities with poorly rganized root mats. Where the substrate is covered by complex root mats (hammocks) these rganisms are not found. In open stands they have an important role of mineral cycling hich is not necessary where a root mat is available to serve as a mechanism preventing xcessive nutrient loss.

The convergence of organisms with mutually dependent relationships and with overlaping abitat requirements results in the close associations of species found together in natural tands. These species are said to have high fidelity with one another. In another sense, his overlapping of functions serves as a survival mechanism for the ecosystem. If one omponent is lost or impaired in function, there are other components which perform suffici- ntly similar functions, that the overall system is not severally stressed. Man builds such edundancy in his space ships such that in the event one mechanism is lost there are one or ore others that can perform the same function. To be on the safe side one maintains equa- able alternatives. Safety in this sense contributes to survival.

While plants greatly modify the environment and affect the kinds of organisms that urvive under their cover, they in turn depend on many of these organisms for their own urvival. For example the reader might try this experiment while he visits the Ocala ational Forest: First locate a patch of scrub or sandhill forest where litter has accum- lated and is being decomposed. Carefully examine these litter and notice the profusion of oots penetrating the partially decomposed organic matter. If you lift this mat and examine t you will notice that particles of sand seem to be suspended in the air without any appar- nt support, between the decomposing matter and a plant root. What holds these particles n position? This is one of the more fascinating stories in the forest. You will recall rom Chapter (II) that plants are the producers of organic matter in the forest through the rocess of photosynthesis. They require sunlight, water, chlorophyll, CO_2 and raw materials uch as mineral nutrients, to perform this important function for the other members of he community. They receive light from the sun, CO_2 from the atmosphere, water from the oil, they manufacture their chlorophyll but must absorb nutrients from the soil. The soils f Florida, however, are very poor in their nutrient composition and are prone to rapid eaching and loss of minerals when it rains. For this reason the quantity of minerals vailable is critical to the community's growth and survival. The symbiotic relationship hat has arisen between the organisms decomposing organic matter and those that produce rganic matter (the plants) is therefore fascinating and of critical importance to plant and animal survival and thus the survival of the ecosystem. It turns out that the sand particles are not suspended in the air by magic but instead they are held there by microscopic organisms known as fungi. These fungi decompose dead matter into its component water, carbon dioxide (products of respiration) and minerals. They are connected to the plant roots by filament-like structures known as hypae and may actually pump the minerals back into the plant or at least make them available to the plant. In return they obtain more organic matter from the plant roots and detrital fall. This is called symbiosis of the form, mutualism (figure 82), as it is thus advantageous to both plant and fungi and to the community in general; it precludes the loss of valuable minerals to the lower depths of the soil profile. When nutrients actually leach to the lower horizons, those animals which burrow become the last biological link of the community to re-capture its precious mineral resource. Through this service, ants, gophers, worms, etc. justify their membership in the biological community.

The roots of sand pine trees are centers of many symbiotic relationships. For example they also associate with other kinds of fungi that actually live in the root and fix atmospheric nitrogen. The nitrogen unavailable in this form to the sand pine or most any other plant, is converted into a compound which is available for plant metabolism. Nitrogen is important in the construction of proteins. These very important fungi are called mychorriz and feed on organic matter supplied through plant photosynthesis and transported in the sap through plant translocation. Also, in the sand pine root there is a symbiotic relationship with other sand pine roots. This is called root grafting. As you walk through the forest you will notice that in older stands, the density of trees is less than in young stands which seem very crowded. As you might expect those stands with crowded trees will have greater competition between trees for the resources in the soil, such as minerals, and wate as well as light. When trees are crowded some individuals graft their roots, that is, the roots of one tree comes in contact with those of another tree and establishes a communication between trees such that they can exchange organic and inorganic materials. These grafts enhance the chances of success of those trees in competition with trees without grafting. As a result they survive while the others don't. Thus, in an old stand we might expect many of the trees to be interconnected by their roots. Another example is the turke oak of the sandhill. Part of their ability to quickly become re-established after a fire is derived from their large root mass which is interconnected. The regenerating individual have a large single pool of potential energy to draw upon prior to establishing their photosynetic network.

Sand pine is a fascinating tree. It not only has symbiotic relationships with fungi, and other trees and animals, but also with a physical factor such as fire. The cones of the sand pine open to release its seeds, and these in turn only germinate after exposure to the heat of a fire. This accounts for the even age appearance (see figure 67) of the sand pine stands in the Ocala. After each natural or man made fire, all available cones germinate, thus producing a high density of seedlings all of the same age. Other trees such as oaks and hickories also depend on symbiotic relations for germination and reproduction. Squirrels justify their membership in the biological community by busily collecting and many times burying fruits and nuts of many trees which depend on this kind of treatment for their germination and propogation (see figure 83). Plants like the honeysuckle depend on insects for their pollination.

Intercommunity relationships do not end with the plant component. They continue and become more dramatic and complex with the animal members of the community. A herbivore, such as a deer in the Ocala National Forest, may have numerous symbiotic relationships in the ecosystem. The relationships of deer within an ecosystem are diagrammed in figure 87.

Any gardener knows that a well pruned plant grows faster, looks better and is more vigorous. Thus, we spend long afternoons pruning our plants. In nature, plants also get this kind of attention by the many herbivores that roam the forest. In the Ocala National Forest the major herbivores are deer, hogs, bears (in reality an omnivore) and insects. The first three are generalists covering a large territory while the insects tend to be quite specific. We call this relationship herbivory. In addition to herbivory, deer are nvolved in competition with other herbivores with similar diets. For example, deer, hogs, nd bear all like to eat acorns and berries from palmetto palms. Therefore, they compete or this food. While competition may become severe under certain conditions, such as when ood is very scarce, the heavy mortality which occurs in the competing populations should ot be labelled as detrimental. At this point we must emphasize the idea that all natural elationships in a forest or regional ecosystem such as the Ocala National Forest are of a eneficial nature to the biological community as a whole, even if on a short term basis hey appear to be of negative benefit to a few individuals. What are the beneficial spin-ffs of competition? For the populations involved, competition is an expression of natural election. It results in the survival of those animals that are best suited to perform heir role in the community or organism. Therefore competition enhances the efficiency of he community in processing its energies and minerals. It also prevents organisms from vereating a certain food supply. When a particular food supply becomes low, competition or it increases and thus certain individuals must seek their food elsewhere.

In the Ocala National Forest, bear, hogs, and deer are migratory and thus seldom overat the food supply in any one area. In a 1958 study, one deer was found for every 101 cres of forest, while food was available for one in every 38 acres. Such is the margin of ature; a margin that is foolproof in terms of overgrazing and subsequent degradation of the abitat. Hunters sometimes cry foul, and demand that herd sizes be increased. Is this wise?

Another relationship of deer is that of predation. Deer are victims of (wild) dogs and ictims of predation by man. Frogs prey on insects and in turn are preyed upon by snakes. agles, ospreys, falcons and hawks prey upon rabbits, fish, small mammals, reptiles and amhibians. In fact, predation is ubiquitous in all of nature. One has only to stand still minute while walking through the Ocala National Forest to observe nature at work. Again, redation seems negative for the eaten but good for the eater. In fact, predation, like ompetition, is good for all. The community benefits from its parts eating each other. If e remove all the predators and controls of one species in the Ocala National Forest, soon hey would not have such magnificent assets. Deer, for example, could destroy the forest n a few years if left without any population control; or more likely the herd would die ack. One of the primary roles of predation is population control. Natural selection is nother. By selecting certain types capable of hunting and not being hunted, predation owers the probability of disease by eliminating individuals as they age. Predation also aintains the flow of energy and matter in the system at rapid rates, thus preventing the ystem from slowing to a grinding stop. Can you visualize a city without money flows? imilarly, a community without predation is unlikely to survive. A deer herd as an interal part of an ecosystem is diagrammed in figure 87.

We could fill a book with examples of interrelationships, but it would not convey fully ow the interrelationships all interact to maintain the ecosystem and perpetuate its surival. To achieve this we must look at each community as a functional ecosystem.

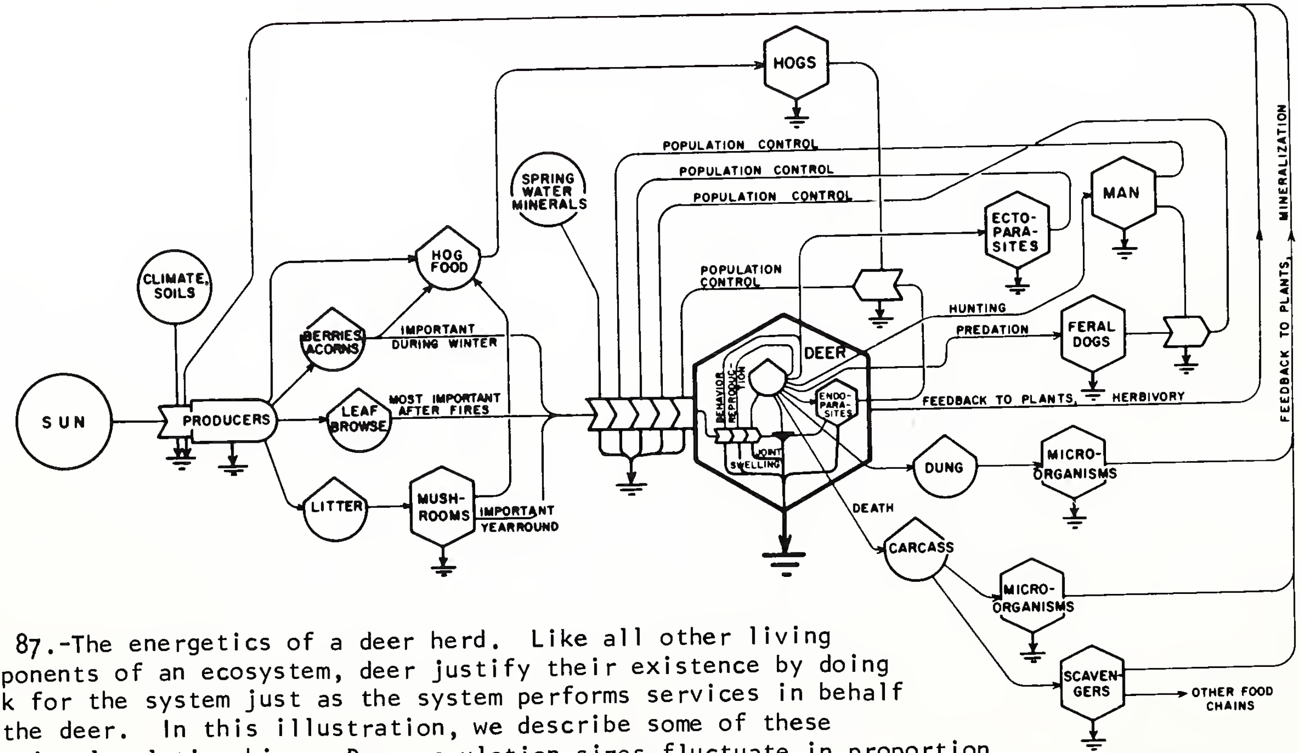


Figure 87.-The energetics of a deer herd. Like all other living components of an ecosystem, deer justify their existence by doing work for the system just as the system performs services in behalf of the deer. In this illustration, we describe some of these functional relationships. Deer population sizes fluctuate in proportion to the amount of energy available for their growth and maintenance. When the herd becomes too large, endoparasites (internal) and ectoparasites (external) which are (density) dependent on deer begin to reduce the herd size. Evidence also suggest that when hogs are abundant, the impact of endoparasites is multiplied as was the case with screw worm in Florida last decade. Similarly, large deer herds offer more hunting opportunities to man who together with his hunting dogs also serve to cut back on the population size. Occasionally, however, these dogs are lost to run wild (feral) and become a predator on deer. The deer uses its energy internally for many functions such as for behavior and reproduction. However, under heavy population pressure, joint swelling may occur which drains energy from the deer. All of these examples reflect the work of nature, and to an extent man, in maintaining a deer herd. The deer in return, maintain the producers by grazing (herbivory), by contributing dung which through decomposition recycles nutrients back to the plants, and by supporting other food chains through the carcasses of dead deer. Another important role of deer in the Ocala National Forest system is the concentrating of nutrients in spring water, transporting them among plants where they serve as a fertilizer. Through this process the deer obtain their mineral requirements from the mineral spring water. Normally, animals must lick mineral rocks or salt deposits to satisfy

THE ECOSYSTEMS OF THE OCALA NATIONAL FOREST

The Sand Pine Scrub Ecosystem

The sand pine scrub and the long leaf pine-turkey oak sandhill communities share occupancy on Florida's elevated, well-drained sands of marine origin. In terms of how these ecosystems are adapted to survive in these environments, both exhibit similar characteristics, although the adaptive mechanisms differ considerably. Both the scrub and the sandhill systems are adapted to survive periods of water deficit, periodic fires and the low soil fertility associated with well-drained sands. The adaptations of each system are so exact that the survival of each is dependent upon these environmental (forcing) functions. In our discussion of the behavior of the scrub ecosystem and later the sandhill ecosystem, keep in mind the adaptive differences, but more important, see if you can recognize that the functions and processes all contribute to equivalent roles.

In figure 88, the scrub has been illustrated in terms of its major components and the major flows of energy linking those components into a viable ecosystem network. Although a wealth of additional detail could be added to the diagram, it is questionable that it would tell us any more about how a system processess its energy and maintains its nutrient cycles. To a large extent, the information we are seeking determines the elimination or addition of detail. For instance, if we wanted to know how the consumers perform their role in the system, we would use diagrams similar to those in Chapter VII or the web diagram in figure 36, because a systems model tells us little about the flow of energy through the consumers. Likewise, if we wanted to learn how sand pine functioned, a model similar to that in figure 8 would be more appropriate. In this final chapter, we are concentrating on the structure and function of whole ecosystems and how the behavior of a specific system is related to the perpetual survival of that system. All the information in the world on species, populations, physiology, taxonomy, feeding habits, etc. would tell us little about ecosystem behavior until it was interpreted within the context of the whole system. Remember that an ecosystem is the smallest unit of life that can exist in relative isolation and that the biosphere is the only perfect example of an ecosystem. Thus, in figure 88 we look at a unit of life called the scrub, and explore how the system, and not the species, is adapted for survival.

Scattered around the periphery of the illustrated scrub model are circles which represent the major forcing functions or energy sources which power the system. The primary source of energy is the sun, which is shown contributing solar energy through a switch and workgate to the system's producers: lichens, pine, oaks and assorted successional or system repair species. In order for this energy to be perpetually assimilated by the scrub, it must be periodically destroyed by fire which initates the repair mechanisms through a switching action. Fire also creates ash which contributes the mineral nutrients necessary for growth and is shown entering the workgate. Similarly, fire acts as a switch on reproduction in that, although many seeds may be present, fire is necessary for successful germination and subsequent establishment in the system. In order for fire to perform its role of controlling regeneration, there must be sufficient water for seed germination, but not so much that the litter is wet and thus cannot catch fire as a result of lightning strikes. This combination of factors is illustrated by two switches being turned ON and OFF by seasonal rain, and by the role of dry air in drying out the fuel and lightning to set the fire. You must think through this sequence in the model to fully appreciate how all biotic and abiotic factors must be exactly programmed to take advantage of fire. It is an excellent example of an adaptation of an ecosystem (not just a species) to the prevailing environmental conditions.

In the model we see that the nutrient cycle is maintained in part by the periodic fires and in part by the dominant plants which contribute their non-functional parts (old leaves, twigs, fruits, etc.) to the litter compartment where decomposition occurs. As an example of the necessary level of detail in a model, note that only pine and oaks are shown contributing litter. Although all other plants and animals also end up as an energy source for the decomposers, their input is very small in comparison to the input from the dominant pines and hardwoods (therefore they have not been illustrated). The litter compartment is

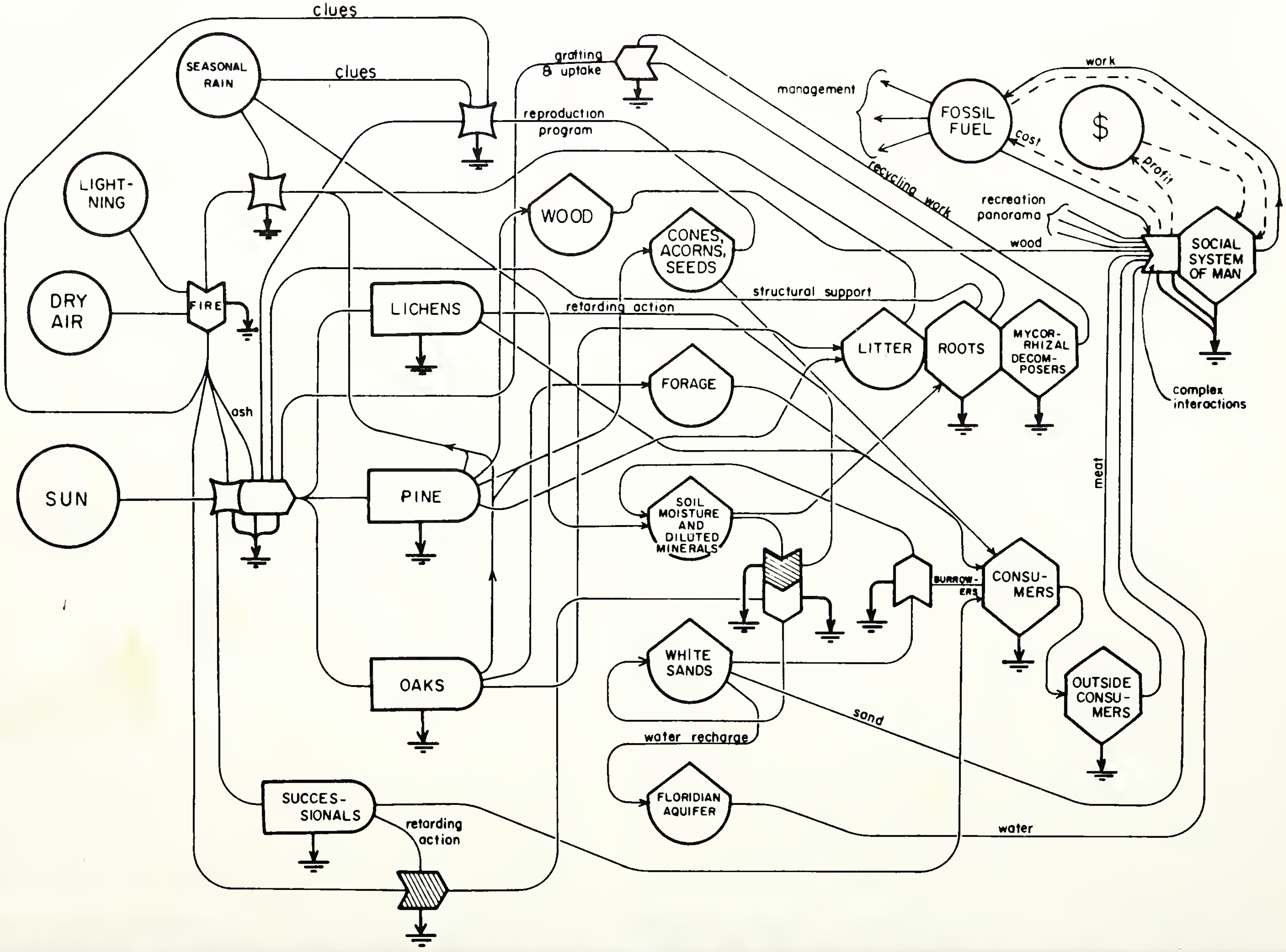


Figure 88.-An energy diagram of a sand pine ecosystem

shown contributing nutrients to the roots, and the roots link back to the main workgate on the overall system's productivity. In addition to the direct uptake of nutrients from the litter by the roots, the role of mycorrhizal decomposers is illustrated as a pumping action (workgate) on this flow. You will remember earlier we discussed how the mycorrhizal organisms decomposed the litter and thus served as a direct pipeline to the roots, and also how the roots of similar species were beneficially grafted together. As shown by the workgate (grafting and uptake) at the top of the drawing, this method of internally circulating the nutrients of the scrub is critical to productivity. Because the scrub, and also the sandhills for that matter, do not receive nutrient rich runoff from other systems, there are no adaptations for trapping this inflow as it occurs in swamps and marshes. Instead, without an external source for such nutrient input, through efficient recycling the scrub is excellently adapted to retain the nutrients it already has and to minimize loss. Note also the role of the consumers in this regard. Outside of the biological network of the scrub, nutrients may be lost through leaching to lower and lower soil depths. This occurs rapidly in the sandy soil as water percolates down to the Floridian aquifer. The burrowing activities of many of the consumers bring this material back to the surface where it is then once again available for intake by the roots. This pumping role is illustrated by the workgate on the flow from sand to soil. By actual count, there are approximately 4370 animal-burrow mounds per hectare, and each mound, on the average, weighs about 1 kilo. If this much earth were brought to the surface in one year, it would amount to about 4.4 metric tons per hectare per year. Of course, burrowing activities go on year round, with old burrows disappearing and new burrows being created. Thus, these figures represent a very low estimate; it could actually be 2 or 3 times higher.

Two other important functions within the scrub have effects on the flow of nutrients between the upper soil and the lower positioned sands. The first is the role of the lichen in retarding the flow (a negative workgate) by covering the forest floor and intercepting available nutrients. The second is the effect of the successional repair species (see figure 26) which are initiated by fire and dominate afterwards. The rapid growing individuals thrive in the ash of the fire and utilize the available nutrients. If minerals are utilized in the new plant structure, they will be prevented from being leached out of the system.

As noted previously, all of the consumers of the scrub ecosystem have been grouped into one functional component, even though each could have been detailed as the deer were in figure 87. The scrub consumers feed on three major compartments, although each compartment n the diagram is ultimately a source of energy for some organism. Seed, forage and successionals are shown as the three major energy sources for the consumers.

Thus far we have described some of the ecosystem mechanisms and component roles of an ntact, normally functioning scrub system. Let's now look at man and how he relates to the scrub and compare his functions with the functions of intact ecosystem components. The scrub provides many public service benefits. Among these are: (1) water, contributed to in part by the aquifer recharge capability of the scrub, (2) white sand for commercial uses, such as in concrete, (3) wood, primarily for the pulp and paper industry, (4) meat, through man's action as an outside consumer, in this case a top carnivore, and (5) the many benefits of recreation, aesthetics, panorama and green space. Man is the perpetual recipient of all of these benefits (except the mining of sand which is a non-renewable resource) so long as he does not take too much and does some minimal amount of work to maintain an intact viable system. We recognize this maintenance on the part of man as conservation.

We have seen in the model of the scrub, and in the subsequent models, that each living component of an ecosystem receives energies from the system and also rewards the system through some sort of work-service feedback, for instance, the decomposers which recycle nutrients. Each component has a feedback into the system or does work which benefits the system, and any component which does not provide such an ecosystem service cannot survive n that system. When man couples his social system to a natural ecosystem, then he too must provide some work function back into the system in proportion to the work services, such as food production, he obtains. This mechanism is illustrated in the upper righthand corner of the model. Man is shown receiving the benefits of the scrub amplified by our fossil fuel economy. For example, the car, camping equipment, and camera, products of our technology, allow us to visit and experience the scrub. Likewise, wood cannot be harvested without saw pulpwood, trucks and supervisory control. To maximize these benefits man does work in the economy from which he receives the wherewithall to interact with the scrub. The dotted lin in this sequence represent dollar flow; note that dollars always flow in the opposite direction from energy. Man's feedback back into the scrub is shown as a management which he exercises by supplying those factors which are limiting and by knowledgeably stressing the system to produce some desired result. The specific role of the forest manager is to rewar the forest for the products received, and to do it at the lowest possible cost. Whereas nature has always provided man with more than he gives back in the form of management or cc servation, our National Forest ecosystems are better off in this regard than those not receiving any reward feedback. Can you think of an ecosystem from which man receives a publi benefit service, but for which man performs no maintenance work?

The Longleaf Pine - Turkey Oak (Sandhill) Ecosystem

Like the sand pine ecosystem, the sandhills are communities of low diversity whose structure and function reflect adaptations for survival in an environment characterized by seasonal water deficits, periodic fires and low soil fertility. The sandhills, the sand pine scrub, and their geographical and successional variants are the ecosystems which dominate the areas of highest elevation and "driest" soils in the Ocala National Forest. Thus, we might say that these two systems represent two ways in which life may adapt to a similar class of environmental conditions.

Like all ecosystems, the sandhill system is self-maintaining, self-reproducing and self-organizing, butthese characteristics are probably more evident in the sandhills than in other ecosystems. Figure 89 illustrates the major functional components and the major flows of energy which perpetuate its continued survival. The sun is shown providing the energy for photosynthesis in four producer components: the longleaf pine, the turkey oak, other plants, and a grouping we will call fire-susceptible plants. With the exception of the longleaf pine, the species of the other producer groups may differ from site to site. For instance, the dominant oak could be post oak or bluejack oak. The fire-susceptible plants are distinguished from the other groups in that they are competitors for the resources of the site. Fire is shown to be regulating this competition through its frequency and intensity by operating as a switch. When the switch is ON, its frequency and intensit represent the normal conditions for which the sandhill components are adapted. The switch is turned OFF when its frequency and/or intensity are significantly altered through fire prevention. Without fire, those producer species normally controlled by fire become abundant and exert a stress (shade, competition) on the reproduction of longleaf pine, turkey oak and associated components of a viable sandhill system. Unless the fire-susceptible species are controlled by fire, the system progresses into a mixed hardwood forest. Fire not only provides the open space for the germination of seed, but also provides the reproductive clues which initiate new reproduction (first switch in sequence) and stimulate regenerative activity in the root system (second switch in sequence).

The sandhills are obviously very similar to the scrub, in that their existence is perpetuated by fire although the mechanisms are distinctly different. The dominant pine, for instance, in the scrub is destroyed by fire and the seedlings initiated by fire will not survive a fire once established. The longleaf pine trees are almost totally fire resistant due to their thick insulating bark and the height (about 120 feet) and spacing of their crowns (see figures 67 and 71 for profile comparison). Also, the seedlings require fire for the control of competition and potentially lethal brown spot which is a disease of lon leaf seedlings. Whereas sand pine fires are totally destructive of the existing structure sandhill fires sustain the existing structure. There is an exception to this which is a result of fire prevention on the sandhills. When fire is excluded for many years, fire-susceptible species begin to dominate and there is a buildup of litter on the forest floor Thus, when there is a fire, the abundant fuel creates sufficient heat to eliminate any you longleaf pine but not the turkey oak which regenerate from their underground interconnecte root mat. Under a reduced frequency of very hot fires, the system becomes dominated by tu key oak and other species which are adapted for survival under a different fire climate.

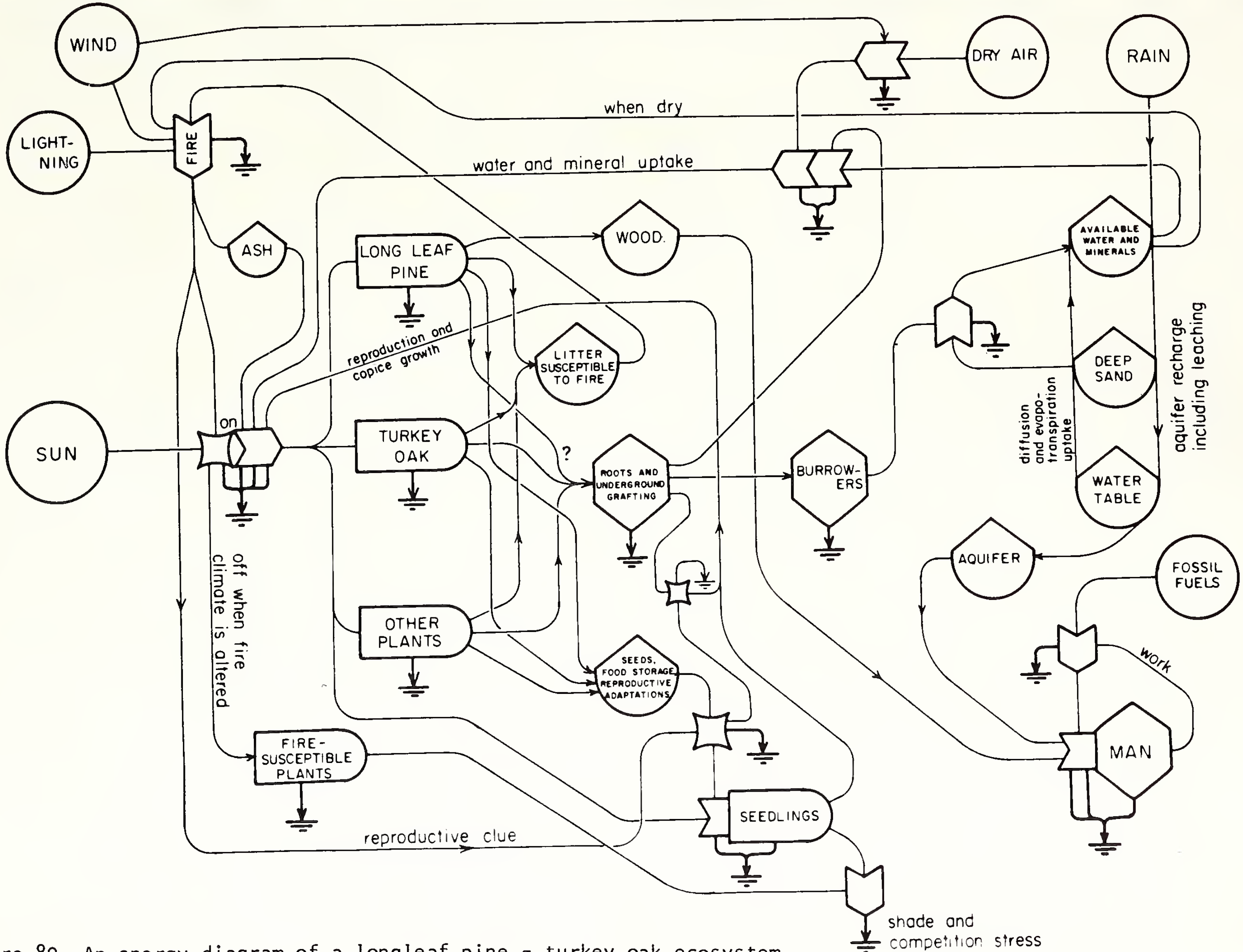

WIND
LIGHT-NING
FIRE
ASH
SUN
on
off when fire climate is altered
DRY AIR
RAIN
when dry
water and mineral uptake
LONG LEAF PINE
WOOD.
TURKEY OAK
OTHER PLANTS
reproduction and copice growth
LITTER SUSCEPTIBLE TO FIRE
?
ROOTS AND UNDERGROUND GRAFTING
BURROW-ERS
SEEDS, FOOD STORAGE REPRODUCTIVE ADAPTATIONS
FIRE-SUSCEPTIBLE PLANTS
SEEDLINGS
reproductive clue
shade and competition stress
AVAILABLE WATER AND MINERALS
DEEP SAND
WATER TABLE
diffusion and evapo-transpiration uptake
aquifer recharge including leaching
AQUIFER
FOSSIL FUELS
work
MAN

Figure 89.-An energy diagram of a longleaf pine - turkey oak ecosystem.

One of the more interesting species in the sandhill ecosystem is the wire grass, Aristida stricta (see pages 118,127) which has evolved in a fire climate to the point where its existence depends entirely on fire (illustrated as "other plants" in diagram). Unlike sand pine, longleaf pine, turkey oak and similar species which require fire, the wire grass cannot be forced to reproduce or expand its range through any other sort of manipulation or management. The individuals which exist today and which you observe in the sandhills will persist only so long as fire occurs periodically. Stated in terms of energetics, the wire grass has become adapted to utilize an auxiliary energy source (fire) to perform the work of reproduction and propagation of the species. By utilizing this auxiliary source, the metabolic energy saved by not having to maintain and operate a reproductive mechanism, is thus available for other functions which justify wire grass's membership in the sandhill ecosystem. This ecosystem role includes such work functions as (1) controlling the invasion of hardwood tree species competitive with the system, (2) the mutualistic relationship wire grass has with other component species, (3) maintenance of a optimum soil environment with respect to water holding capacity, soil structure and nutrient filtering, and (4) a reduction in rate of accumulation of forest fuels.

The role of fire in reinitiating succession and providing a fertilizer for the new growth is similar to its role in the scrub. The diagram shows the switch controlling successional response and the workgate being operated by the ash. Fire, of course, is dependent upon a fuel supply, dry conditions and an ignitor, which in this example is lightning. Central and southern Florida have one of the highest incidences of lightning in the country. No wonder so many of these ecosystems are fire adapted. You can usually recognize lightning struck trees, usually tall or isolated pines, by looking for a streak of exposed wood running the length of a standing tree. This is the remains of the pathway (the conductive water in the cambium beneath the bark) that the lightning travelled. However, man has so altered the fire climate, on the one hand by fire prevention, and on the other by starting fires when the fuel supply is too large, that the longleaf pine systems of today bear little resemblance to their historic condition.

All systems require dry air in order that water is taken up, translocated to the leaves transpired and lost to evaporation. Not only do the plants require water per se, but they also require the root to shoot stream flow for the uptake and translocation of mineral nutrients. Dry air is thus shown as an auxiliary energy source powered by the wind and pumping the transpirational water. The second workgate on this flow indicates also that the uptake is proportional to the abundance of roots and their concentration in a volume of soil. Thus it is easy to see why turkey oak with its important underground structure can so easily take over this system when the fire climate selects against species without a large interconnected root mat.

This model also re-emphasizes the role of the burrower in the recycling of nutrients in an ecosystem where the propensity to lose nutrients is so high and where there is no source of nutrients to replenish those that are lost. The soil-water-nutrient relationship is shown in the upper right with rain moving downward through the upper soil (available water and nutrients), through the deep sand and then into the water table and aquifer Some of the nutrients carried downward in this flow are brought back to the surface where they are once again available for plant uptake.

The aquifer is also shown benefiting man as a water supply, thus drawing attention onc again to the Ocala National Forest as a recharge area. Only one other of the many public service benefits man receives from the sandhills is illustrated: wood. Although longleaf pine produces some of the very best southern yellow pine lumber, in areas where longleaf contributes to the overall panorama and integrity of the forest, harvesting has been reduce. This is partially in response to the fact that the sandhills of historic times, composed huge longleaf pines, scattered oaks and a carpet of wire grasses, have almost disappeared due to a lack of conservation. Also, the recreational experience provided the public in these areas is of greater value than the longleaf timber.

The Xerophytic Hammock Ecosystem

Both the scrub and the sandhills tend to be maintained as long-term steady-state ecosystems through the rejuvenation processes of fire. Should the fire climate become altered, in terms of frequency or intensity, and be maintained as altered, then both ecosystems will develop different steady states characterized by some different level of maturity. Remember from figure 27 that with increasing maturity, ecosystems tend to have greater biomass, diversity, structure complexity, stability, respiration and a lower net productivity. The xerophytic hammock ecosystem represents the successional climax and steady state of scrub and sandhills when the fire frequency and intensity have been eliminated as a stress. (If the frequency and intensity were instead increased in the sandhills, for instance, the new steady state could be a pure stand of turkey oak of low complexity, low biomass and higher net production, etc.). For an example of a xerophytic hammock ecosystem, we will use the successional climax which occurs on sandhills from which fire has been eliminated.

As discussed previously in figure 89, the sandhill vegetation may be categorized as being fire-maintained or fire-susceptible, according to species. Thus, when adaptative under the prevailing fire climate, fire-susceptible species are controlled and the adapted species are maintained by fire. Should fire be eliminated, the fire-susceptible species gain dominance and the system develops (matures) at the expense of the fire-maintained species. The result is a xerophytic hammock.

Of particular importance in the continued maintenance of a xerophytic hammock, once established, are the dominant plant species, the soil system and the water balance. These are diagrammed in the energy model of the xerophytic hammock in figure 90. The major plant producer compartments are a diversity of trees and shrubs and a ground layer of herbaceous (non-woody) plant species. Spanish moss, also a producer, is illustrated separately to represent all epiphytes (plants which grow on other plants) and their role in this and other systems. The trees and shrubs are maintained by two major feedbacks and an externally derived auxiliary energy source. To a large extent these are characteristic of all terrestrial ecosystems but are best exampled in the more mature ones. The first feedback concerns the role of the consumers who derive their energies from the producers and in return perform certain services illustrated as specialized work. Many of the reward feedbacks may be observed in this or other systems. The following examples should guide you in looking for others:

(1) The specialized work of grazing leaves to maintain optimum leaf area and spacing. Leafy, green material is an energy resource for many herbivores. In their grazing, they seldom take more than about 12 percent of the leaf biomass and tend to concentrate where the leaves are more abundant. The grazers are specialized in that one species will graze a particular plant species and may also be specific as to whether they will eat old leaves or young leaves, sun leaves or shade leaves, or at certain times of the year and not others. The result of their highly selective dietaries and locational preferences in space and time keeps the canopy from being overstocked with leaves which would prevent adequate light filtration deep within the canopy. Many other benefits occur such as better diffusion of gases and quicker recycling of nutrients, all of which collectively serve to amplify the productivity. Only in instances where the system is not balanced will herbivores react through excessive defoliation to regain the steady-state condition. You can calculate the grazing pressure in an ecosystem by determining the percentage of a leaf which has been chewed away. You must do this many times as not all leaves are chewed equally. If you obtain something significantly less than 7 to 12 percent (or none) eaten, or a figure significantly greater (say 60 percent), try to question the reason why (taste, surface, herbivore population, etc.).

(2) The specialized work of tearing down old structures. Trees and shrubs which are past their prime in terms of productivity, or which have completed their role in the ecosystem, occupy space which could be used by better functioning components and tie up nutrients which may be needed elsewhere in the system. As nature always selects for maximum energy flow, these individuals have to be eliminated and their minerals recycled. There is no end to the variety of mechanisms which serve to tear down the old structure. For instance, there are numerous invertebrates (ants, termites, beetles, millipeds, etc.)

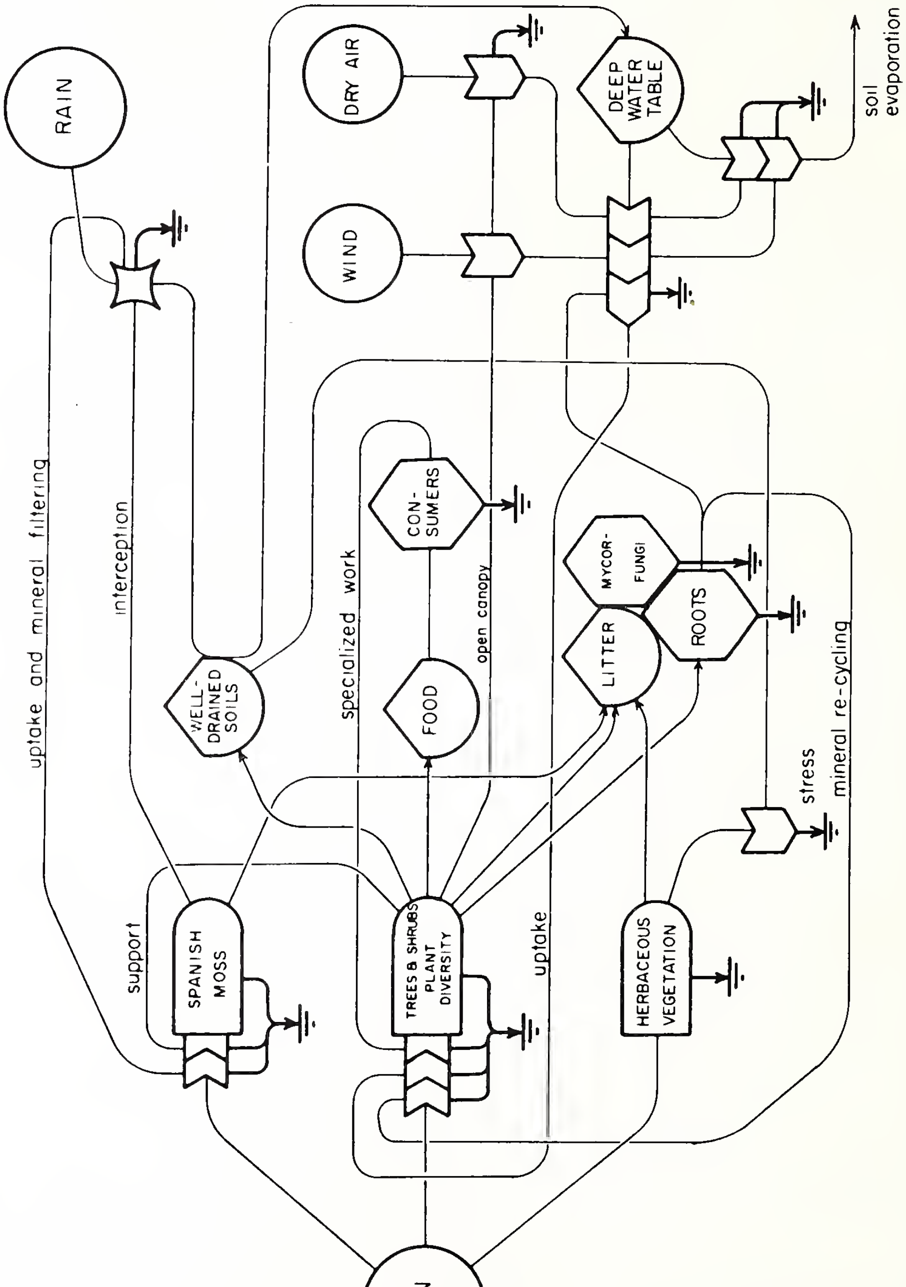


Figure 90.- An energy diagram of a xerophytic hammock ecosystem. Emphasis is given to certain ecosystem processes common to many ecosystems in the Ocala National Forest.

which attack and weaken the structure. Wind and heavy rain break apart weakened limbs and sometimes whole dead trees. Bears climbing a dead honey tree break limbs and peel bark. Look for signs of these activities by, for instance, peeling away a piece of bark of a dead tree. Can you look at a piece of dead wood on the ground and determine how it got there?

(3) The specialized work of assisting in the reproduction of a plant species. We have already cited several examples of this work function (see figure 83), so we will just summarize in order to focus your observations. Squirrels bury the acorns of oak trees with the notion of retrieving them at some later date. Have you ever seen a squirrel searching and digging for a lost acorn? Will that oak tree seed be found, or will it germinate to grow into a new individual? Other animals consume fruit but do not digest the seed. These seeds are usually dropped in nutrient rich feces in other areas. Look for some dry scat (animal droppings) and see how many seeds you find. If there are none, can you identify what the animal ate by looking for such things as hair, bone, feathers, insect skeletons or plant fragments?

The second feedback in this ecosystem is one which has been discussed several times now. Over 80 percent of the energy flow passes through the decomposers and attention is drawn to this mechanism once more because of its importance in all ecosystems. The decomposers receive organic detritus from the producers and feed back mineral nutrients to the plants which through the workgate maintain continued production. As we earlier discussed (see page 161), some portion of the total return flow of nutrients results from the mutualistic association of fungal mycelium and roots (a mycorrhizal relationship). One of the characteristics of more mature ecosystems is the tightly closed mineral cycles which serve to prevent loss of needed nutrients. Maybe this tight cycling attests to the efficiency of this relationship.

The major energies involved in circulating minerals are the results of a linkage of amplifiers powered by auxiliary energy. To a large extent, the xerophytic hammock is similar to the sandhills with respect to the degree of air turbulence and mixing within the system. The diagram illustrates this to be a function of the % closure of the canopy, that is, the openess of the canopy. The open canopies of the scrub hammock and the sandhills, together with the ragged canopy surface, amplify the continual movement of wind and dry air through the photosynthetic strata. Both of these auxiliary energy sources are shown interacting to draw water from the deep water table which is then available for plant uptake and direct evaporation from the soil. Remember, that even though evaporation represents a loss of water from an ecosystem, the evaporative process cools the environment. Water uptake in plants is the result of transpiration. In the flow of water from the root system to the photosynthesic-transpiring leaf tissues, minerals are translocated to the biochemical processes where they are incorporated into organic matter (refer to figure 9). Without the interactions of wind and dry air, transpiration would not occur, water flow would cease and the rate of photosynthesis would become mineral-nutrient limited.

Although we have discussed mineral cycling in terms of broad ecosystem functions, individual species components sometimes have very specific and important roles. For instance, in this energy flow diagram, the role of Spanish moss is illustrated. Spanish moss is an epiphytic plant which utilizes other plants for support. It is not a parasite in that it is capable of photosynthetically meeting its energy requirements. Its specific role is the mechanism through which it meets its water and mineral requirements. The absorbing and water collecting properties of its structure intercept rainfall and thus stop a portion of it from reaching the soil. In figure 39, the proportion of rainfall intercepted by the canopy components is shown to be about one-fifth of the total. Spanish moss intercepts direct rainfall, leaf drip and stem flow, all of which contain varying quantities of minerals. The uptake of these minerals provides the nutrient requirements of the Spanish moss and is incorporated in the epiphyte biomass. In addition to other roles which may be suggested for Spanish moss, its role in the mineral balance may be one of the more important. As previously discussed, nutrients not tied up in the biomass of xerophytic systems are subject to loss. However, that portion of available minerals which is intercepted in the water flows and incorporated in biomass is channelled directly in the ecosystem's biological cycles. Shown in the diagram, the detrital output of Spanish moss enters the litter from whence the minerals may be cycled into other processes.

The last major point to be emphasized in this diagram is the stress on the ground layer vegetation caused by excessive drainage of the soils. It is illustrated as a stress only as a way of showing that deep rooted plants are better able to utilize moisture in the lower soil levels. As we now know, the herbaceous vegetation is indeed adapted to this "stress", the elimination of which may be detrimental.

The Mesophytic Hammock Ecosystem

The mesophytic mixed-hardwood ecosystem was referred to in Chapter VI as the steady-state (climax) ecosystem which results when succession proceeds normally in the scrub, sandhills and in some variants of the flatwoods community. The key to this statement is the word, normally. Each of the listed ecosystems is maintained by a specific set of environmental forcing function such as frequency of fire, a high water table and flooding, and/or periods of water deficit. These forcing functions arrest succession by increasing the system's respiratory maintenance; energy thus diverted is not available for further ecosystem development. The term "normally" describes succession under conditions where these forcing functions (or stresses) are non-operative. The mesophytic climax ecosystem was also shown to be the most diverse in species which relates back to figure 27 showing an increase in diversity as the system matures.

In the energy flow diagram (figure 91), the diverse array of components and interrelationships has been summarized in functional groupings to draw emphasis to the system. As shown, the producers are represented by a diversity of species which are maintained primarily by processes within the system. This contrasts with both the scrub and the sandhills in which the producers are far more dependent on the external forcing functions. This is consistent with our earlier discussions relating to the stability of steady-state systems and how all of the internal processes contribute to perpetual self-maintenance and survival. Let's look more closely at the four processes or feedbacks which in the ecosystem contribute to these goals:

(1) The increase in biomass and organic structure increases the total water holding (storage) capacity of the ecosystem. For instance, the soil rich in organic matter and thick litter layer have excellent water-storing characteristics, and, the thick canopy retains the moisture (humidity) within the system. The constant availability of moisture accelerates the dependent processes. Systems lacking this moisture storing ability experience a reduction in photosynthesis and must also spend energy (metabolic) to evolve and maintain water conserving mechanisms (see turkey oak, p.120).

(2) Ecosystems which do not dry out but remain moist are relatively well protected from fire. As this system is not dependent on fire, this insulating property serves to maintain a high productivity and therefore continued survival.

(3) The third self-maintenance feedback is the tight internal circulation of minerals which serves both to prevent losses and to cycle minerals to the proper location when needed. As shown, the major energies powering this process(s) come from dry air acting through transpiration and from the activities in the litter-fungi-root mat complex. The dynamics of the latter has been described now several times.

(4) The last major feedback revolves around the activities of the system's consumers who are, in reality, ecosystem managers. The ecosystem manager is an organism that utilizes a small fraction of the total energy budget and in return provides a service which aids the system in its function and continued survival. If a manager does not contribute such a service then he is not a part of the system and is called an exploiter. Can you think of animals other than man which fits the role of an exploiter? Specific examples of ecosystem managers and roles are scattered throuhout the book.

The mixed hardwood mesophytic ecosystem's self maintenance program is based on an optimum water balance and tight internal cycling of its minerals. Unlike other systems which loose minerals through erosion, surface runoff and biological export, this steady-state system

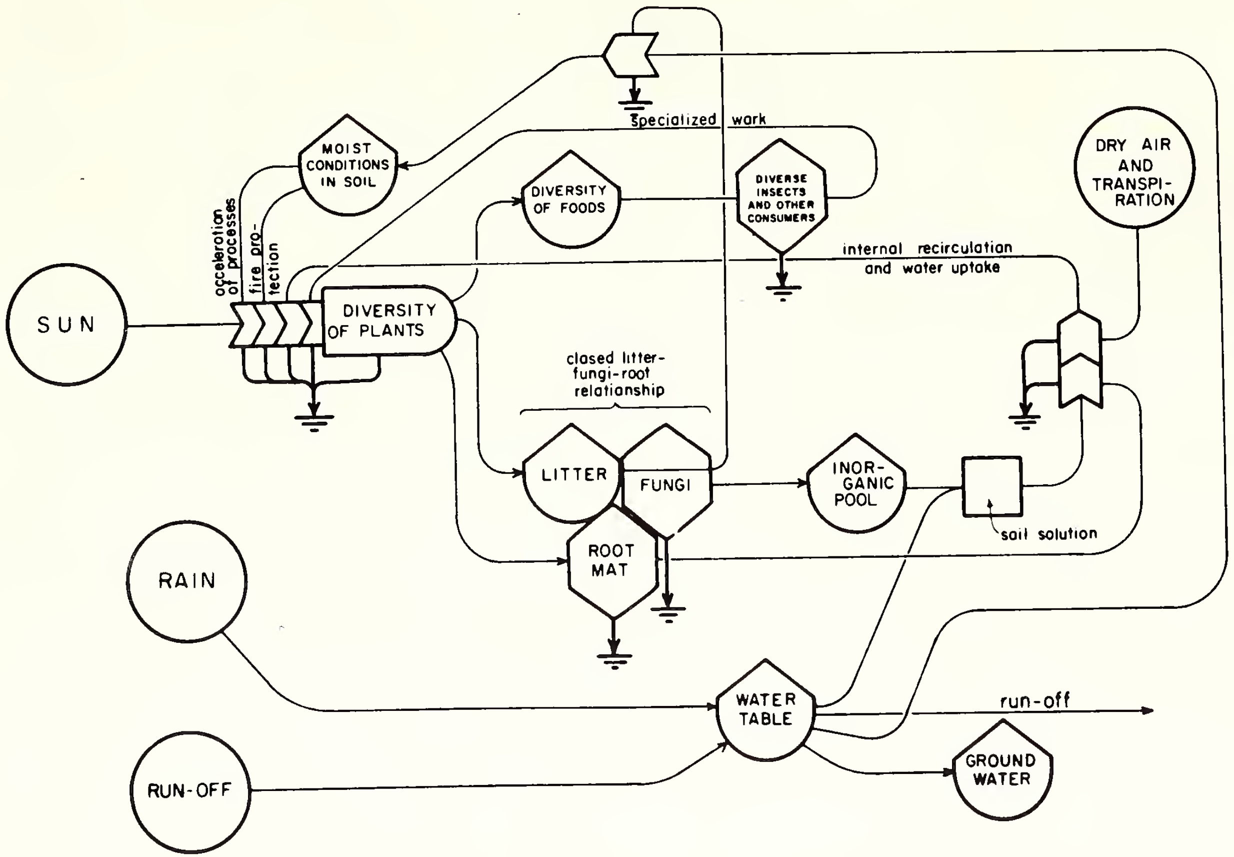


Figure 91.-An energy diagram of a mesophytic hammock ecosystem.

experiences net gains in its mineral stocks. Rainfall and runoff from adjacent ecosystems e this system and for a period become a component in the soil water (water table). In contact with the root mat complex, these minerals are drawn into the system's internal cycles where they are kept circulating. The mesophytic ecosystem is thus a mineral trapping mechanism wi regard to these relatively small flow inputs. Later, we will learn how an ecosystem can tra minerals in very large water flows.

Here is a neat little experiment to perform when you are experiencing this ecosystem, particularly on a dry summer day. Look for the small inconspicuous resurrection fern that appears dead due to its brown, dry appearance. Saturate the plant with water from your cant and return the following day to observe the effect. The "dead" plant will be green and erec and a second watering will further amplify the effect. Plants that have no continual access to water will wither and die unless they receive water at appropriate intervals. The resurrection fern is adapted to surviving the sometimes long periods between rainfall by shutting off its photosynthetic machinery, only to restart it when water is available.

The Flatwoods Ecosystem

Thus far, we have described some major structural and functional adaptations for surviv in ecosystems whose behavior reflects environments generally deficient in minerals and water and whose presence is related to fire. With the exception of the flatwoods, the remaining ecosystems are adapted to a relative abundance of minerals and water and their presence is not related to fire. The flatwoods, however, represent an ecosystem around which the enviro ment oscillates between flooding and drought with concomitant effects on mineral cycling and whose survival is, largely, perpetuated by fire. The community description on p.136 provide the basic information for the flatwoods. With that in mind, plus your observations of the flatwoods, stop now and see how well you are able to understand the model (figure 92) pric to our discussion.

Pine and palmetto characterize the basic flatwoods ecosystem producers which are regula by a switch (fire) and three feedbacks. The oaks (hardwoods in general) are considered separately as competitors controlled by fire through the same switch. Thus, photosynthesis and production occur in the flatwoods components when there is fire to control the successic hardwoods. When there is no fire to control the hardwoods, they (the oaks) assume increasin dominance in the system and account for an increasing proportion of the solar-powered productivity. In the diagram, the switch is shown as being OFF indicating that the basic flatwoods species are dominating the energy flow in the system under discussion.

One of the major forcing functions driving the flatwoods system is seasonal rain which during the wet season contributes to flooding the flat topography. This is shown in the dia gram increasing the soil water, elevating the water table and ultimately contributing to the aquifer. The hardpan, however, retards subsurface drainage which serves as a switch on wate entering the aquifer. Under normal conditions, i.e., with an intact hardpan, this switch is OFF (shown). Flooded conditions operate a workgate on productivity by favoring those specie which are adapted to such conditions and selecting against those which cannot survive floodi During the dry season, the dry air (high saturation deficit) powers transpiration drawing water from the soil. This is shown as a workgate (amplifier) in that transpiration is proportional to the drying power of the air. As previously discussed, transpiration pulls minerals through the root and plant system (see figure B), thus stimulating productivity. The nutrients to which the roots have access may also leach downward and become unavailable as part of the hardpan. This is shown being controlled by the fluctuating water table. The hardpan also prevents roots from penetrating deep into the soil (shown as a workgate on roots) which actually maintains the absorbing root structure within the soil volume where the leachable minerals are located.

Fire is shown to be a function of a low water table, dry air which drives the potential fuel and a spark source which in nature is lightning. When the flatwoods are protected from fire, the successional hardwoods (shown as oaks) become dominant. Thus, the presence of fir is illustrated as a stress on the oaks. No fire and an abundance of oaks creates a root system which can penetrate and thus destroy the water holding integrity of the hardpan. Whereas this stress opens the switch allowing water to possibly enter the aquifer quicker,

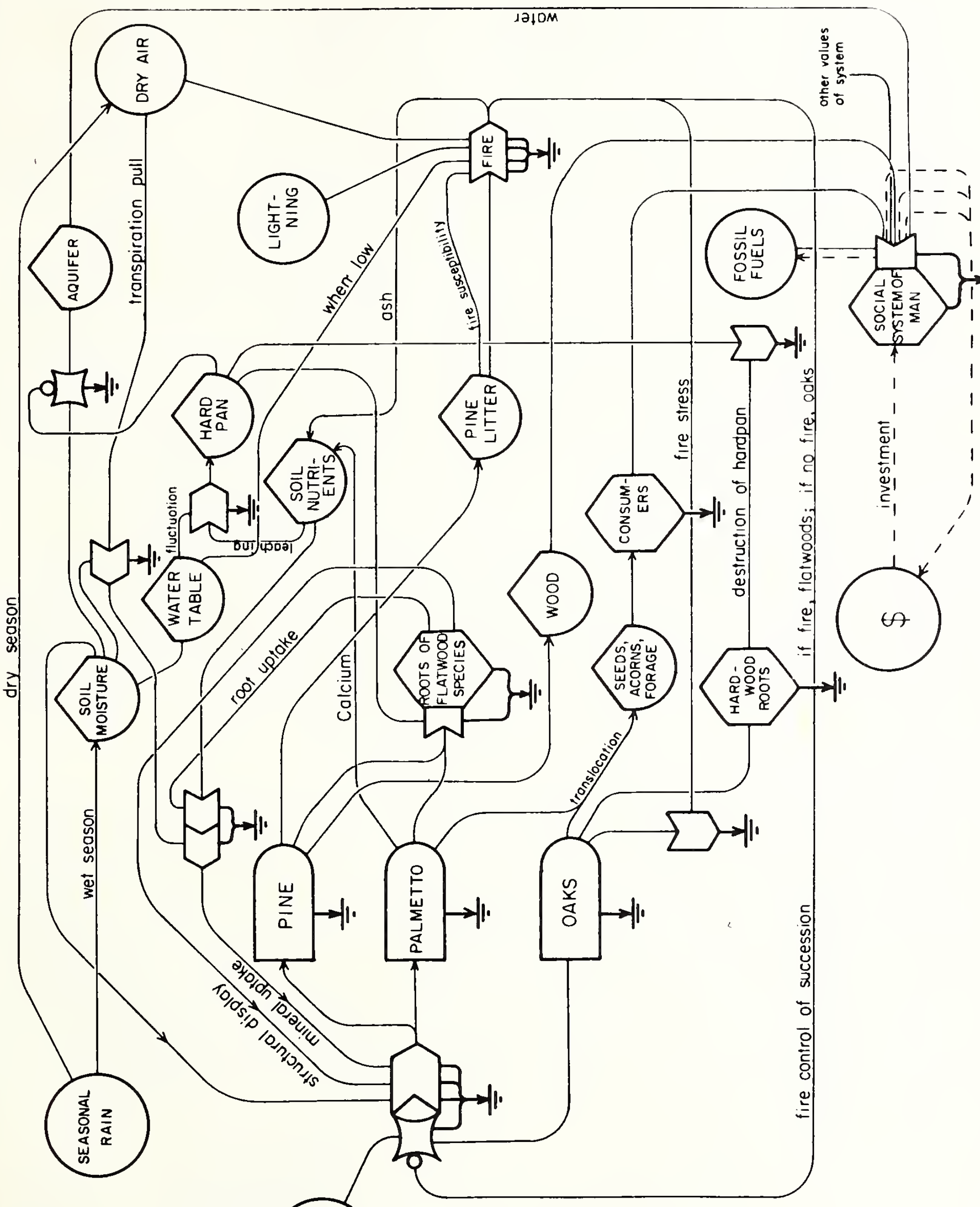


Figure 92.-An energy diagram of a flatwoods ecosystem.

the survival value of the hardpan to the flatwoods is diminished. The pine litter, when dry, provides the primary fuel source for carrying a ground fire which, in addition to recycling minerals, also prevents the buildup of the litter fuel to a point where it would support a really hot fire.

As mentioned previously, some plant species have very specific roles in the circulatio of minerals in an ecosystem (see Spanish moss, p.172). The flatwoods ecosystem provides another example in the role of the palmetto in circulating calcium. All of the nutrient minerals differ in their rates of loss from both living and dead biological materials, and also differ inthe rates at which they are transported by water. Potassium, for instance, which is required in the growth of new tissues, is readily leached (moved out of or through by water and is translocated back into a plant prior to leaf fall. Calcium differs in that once it is tied up in cell wall material (or in bones!) it is not re-translocated but is retained in the structure. Thus, with leaf fall the plant loses more calcium than, for instance, potassium. Because the producers must take up calcium so rapidly to maintain an optimum budget, particularly during the growing season (when new cell walls are being forme there must be an efficient mechanism in the system to make sure it is available. In the flatwoods, this role is performed by the common palmetto. The palmetto concentrates the calcium in the soil and pumps it back to the litter surface as leaf and fruit fall. Thus, the palmetto acts as a "calcium pump" in the circulation of the flow of calcium to ensure adequate available amounts for uptake by the surface feeder roots (see figure 34). This role is illustrated by the direct pathway linking palmetto with soil nutrient. In hardwood ecosystems where dogwood is an understory component, the dogwood trees similarly function as calcium pumps. It is specific roles, such as calcium pumps, that justify species existence in an ecosystem. Unfortunately, many scientists are more concerned about the functional mechanisms than they are about functional roles in the self-maintenance of ecosystem

The flatwoods ecosystem contributes both net-yield products and public service benefit which are summarized in the lower right of the diagram. As shown, their actual utilization in man's social system is dependent on an expenditure of fossil fuel energy. For instance, water is free; man only pays for purifying it for drinking and for piping it from one place to another. Similarly, wood is free and man only covers the cost of harvesting and processing it. Thus, the dollar payments are shown being maintained within man's economy. However, when man repays nature through management, the pathways are similar to those shown in figure 88.

Hydrophytic Forest Ecosystems

Unlike the flatwoods, the hydrophytic forest ecosystems are flooded for longer periods during the year, do not have hardpans, are not fire maintained and are dominated by hardwoods. Inundation usually results from a seasonal rise in the water level of a runoff wate collecting area (lake, pond or sink) or a water transporting area (river or creek basin, flood plain, etc.). The flatwoods, in contrast, flood primarily because the rain which fall on them cannot be removed quickly enough by gravity due to the low, flat topography and a normally high water table. The lowland hydrophytic ecosystems in the Ocala National Forest are best exampled around the southern extremes of Lake George and in the Oklawaha River Bas Previously, we have described the mesophytic forest ecosystem as the one with the highest d versity. However, when one considers that a swamp forest, for instance, consists of both aquatic and terrestrial organisms, then the total species diversity is certainly higher in the swamp forest ecosystem.

The energy diagram in figure 93 describes the structure and function of a flood plain swamp forest as an example of the hydrophytic forest. The other hydrophytic forest ecosystems resemble this system in terms of behavior and public service benefits. The sun, as in all ecological systems is the primary forcing function although the differentiating characteristics of the flood plain forest are adaptations to fluctuating surface waters and the materials within. Flood waters result when the rainfall over a large area in a relatively short period (wet season) of time is concentrated in stream or river channels by gravity.

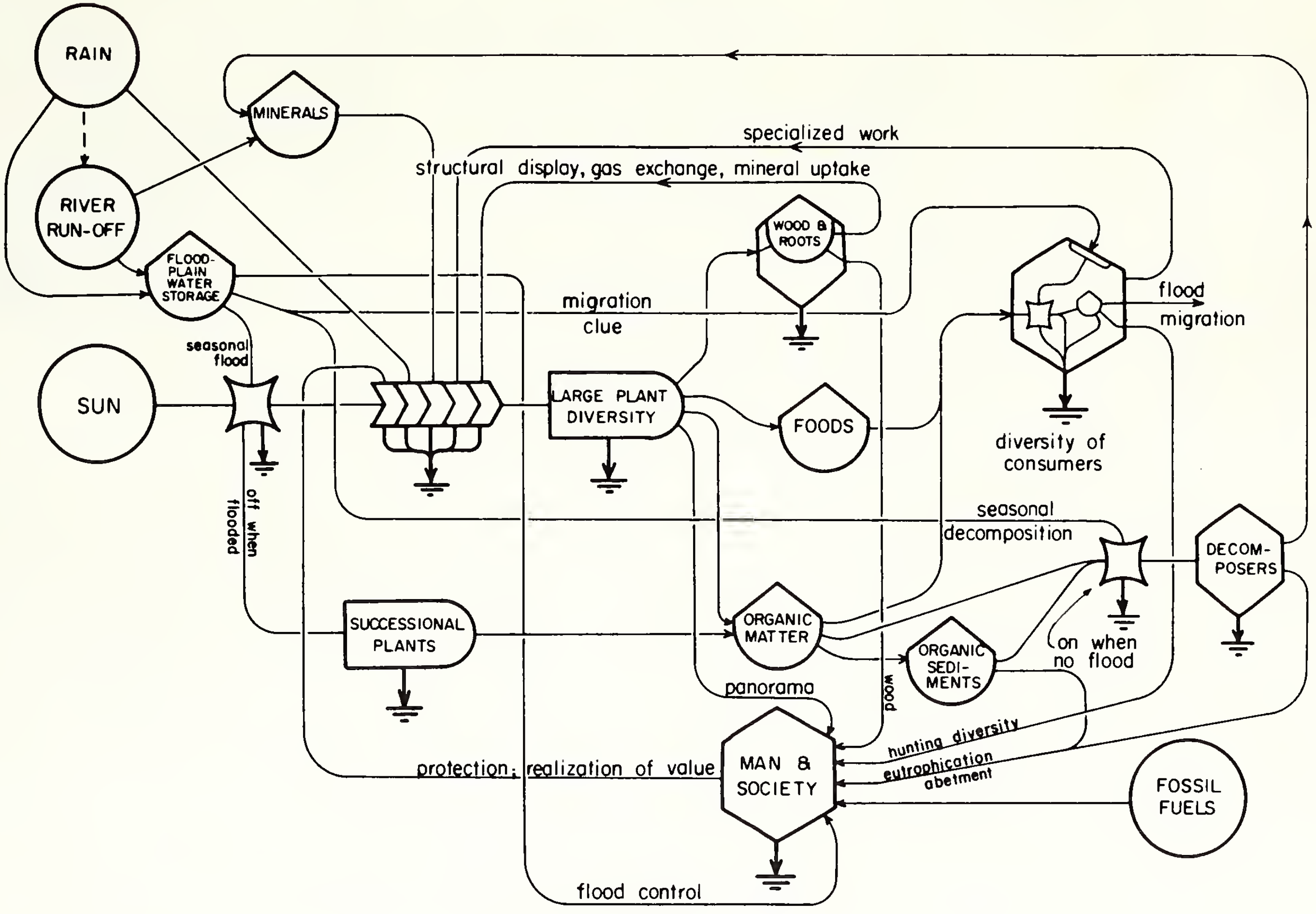


Figure 93.-An energy diagram of a hydrophytic forest ecosystem. The major characteristics depicted represent a flood plain as a type of hydrophytic forest ecosystem.

The channels which normally transport much lower flow volumes overflow and the water spreads out over the flood plain. As shown in the model, these flood waters control those successio which cannot become dominant in areas which flood. Of course, prevention of seasonal floodi permits these species to successfully compete with the hydrophytic species and eventually replace them. The major public service benefit of this ecosystem is the prevention of floo in non-flood plain areas. Were the excessive wet season restricted to just the channel, for instance by channelization and/or diking, the water would race down and flood areas normally protected by the upstream floodplain. Excess water is "stored" on the floodplain by the fac that it is spread over a wide area in which trees, shrub, and ground-surface roughness slow its rate of flow, or velocity. One of man's more humorous plights has been to build on floo plains and then express surprise over being flooded. The flood control benefits of intact floodplain ecosystems is one of the least appreciated free services of nature.

In the first ecosystems discussed in this Chapter, one of the common characteristics shared was the lack of additional mineral inputs coupled with unique biological adaptation for conserving the existing nutrient stocks. In contrast, the floodplain ecosystems are exposed to very large mineral nutrient inputs during the period of inundation. The waters which flow from upstream sources carry with them dissolved and particulate inorganic and organic materials. The load is particularly heavy when the upstream watershed ecosystems loose their integrity or materials such as domestic wastes become a part of the downstream flow. Suspended particulates are carried in fast moving water but fall to the bottom when the flow is sufficiently reduced. Thus, as excess water moves out over the floodplain, the velocity is reduced and the materials settle out. The alluvial soils of floodplains and deltas are so productive because the deposited materials are usually rich in mineral nutrien In the diagram, these minerals are shown to be operating a workgate on productivity. Dissolved materials, such as nutrients in solution, may be taken up by plants directly from the water. The ability of hydrophytic floodplains to help purify water through these mechanisms has given them the name of nutrient traps.

Under certain conditions, such as diking and draining floodplain areas, the nutrient trap or storage may be emptied. The organic matter (consisting of carbon, hydrogen, oxygen and minerals) produced by the vegetation and deposited by flood water decomposes only very slowly until exposed to air. With an abundant source of oxygen in the air, decomposer respiration increases releasing the tied-up minerals. These minerals then are available for re-uptake by plants. As shown, this occurs through the plant respiration organs although they are diagrammed separately. If the process of aerobic decomposition continues, without being controlled by periodic flooding, more mineral nutrients are released than can be utilized by the ecosystem. As a result nearby waters become enriched with nutrients and enter into a condition known as eutrophication. Thus, for the hydrophytic ecosystem to serve effectively as a nutrient trap, flooding must occur as the ecosystem components are adapted for effective nutrient cycling under these conditions.

One of the programmed functions of the lowland hydrophytic ecosystem is the migration o animals in and out of the system. The clue initiating migration is the seasonal flooding. The environment with and without flood waters offers two quite different habitats which are reflected in the changing species composition of the consumers during a year. This is the basis of the high diversity for this ecosystem; the total number species interacting with the system or an annual basis is greater than the number on location at any given time. In the diagram, the internal structure of the consumer component is outlined. The consumers feed on the food materials provided by the system, which represents a continual flow of ener This energy is shown being switched between wet season and dry season species initiated by the migration clue. The small storage represents the standing stock (biomass) of individuals As shown, the consumer component remains functional even though migration occurs. This migr tion switch, like the other two in the diagram, controls the behavior of the hydrophytic flo plain system and each is turned ON and OFF by season flooding. Drainage or impoundment lock these switches after which the system responds to the alteration(s) by succeeding to a mesophytic ecosystem (drained) or an aquatic system without a large tree diversity (impoundment). It must be remembered that either subsequent system will self design a characteristic structu and function with producers and consumers and all other basic components of a viable ecosyste

Problems arise, however, when the new system(s) is considered to be of less value to man than the one replaced.

At the bottom of the energy flow diagram are some of the public service benefits of the hydrophytic floodplain ecosystem, as they relate to man, and a feedback from man back into the system. The intact system provides man with flood control benefits in downstream areas, with a diversity of wildlife and game, and with control of mineral nutrients which could stimulate eutrophication in downstream waters. The feedback, or the mechanisms, by which man repays nature is incredibly simple. All man has to do to operate this feedback is realize the value of this ecosystem and then just leave it alone.

The Marsh or Prairie Ecosystem

Another type of hydrophytic ecosystem is the marsh or prairie. These two differ basically in their respective hydroperiods. The marsh during the dry season remains wetter than the prairie which may become dry enough to burn. Part of the reason for a marsh remaining wet to moist throughout the year is that they (1) are usually located in areas of lower topographic relief, resulting in a higher water table, (2) occur in areas of thick water-holding organic soil, and (3) may reside over a "perched" water table such as occurs under a cypress dome. Both the marsh and the prairie are dominated by a herbaecous cover of grasses, sedges and herbs, in varying proportion, and may also contain scattered shrubs and small trees. However, the general appearance is one of an overgrown field. Whereas the prairies, in particular, appear to be deficient in wildlife, they are in fact both photosynthetically productive and do support a farily rich diversity of species. The energy model in figure 94 describes the structure and function of a prairie, such as Hopkins prairie, in which water and fire are the major forcing functions.

Unlike a hydrophytic floodplain forest, the water received by the prairie results primarily from rainfall with some runoff from nearby areas. This is shown in the model diagram as being the source of water maintaining a high water table. Because prairies do not freely drain like other ecosystems, water loss occurs basically through evapotranspiration, indicated as an environmental factor (summation of dry air, wind, temperature, etc.) operating a workgate lowering the water table. (We have several times now diagrammed the role of dry air in transpiration and the overall effect on producer productivity and thus will acknowledge this process in the prairie but not diagram it.) A low water table and dry fuel, of course, increase the probability of fire which in the prairie (less so in the marsh) occurs relatively frequently. This is similar to the flatwoods ecosystem in which the components are adapted to widely fluctuating water regimes coupled with a characteristic fire climate.

The producers of the prairie are grouped as grassy plants which are shown powering many types of food chains and contributing to litter production. The food chains are diagrammatically lumped into two groups each of which is controlled by a switch controlled by water fluctuation and fire. The two switches reflect the complex interactions of fire and water on the behavior of components of the food chains and in turn the complex behavior of the system. Thus, when one (fire or water) is present the other is not and vice versa. Each condition requires a different behavioral response from the animals, and thus plant-animal and animal-animal relationships in the system change, depending upon the environmental condition. The net result is shown as some kind of specialized work function which reinforces the relationships among environment, consumer, and producer. Some plants exhibit explosive growths following fires and thus attract specialized consumers which move into the prairie in response to an increase in net plant production. Similarly, other plants respond to inundation by flowering and fruiting and thus attract other kinds of consumers. Certain animals avoid dry conditions while others avoid wet conditions. Thus, this environment is one of shifting animal populations and finely-tuned plant phenologies all responding to the fluctuations of the physical environment.

Fire is also the progenitor of other ecosystem functions which serve to perpetuate the system. Fire short circuits the normal litter decomposition by creating ash (inorganic matter) which through mineralization and uptake by plants stimulates plant productivity.

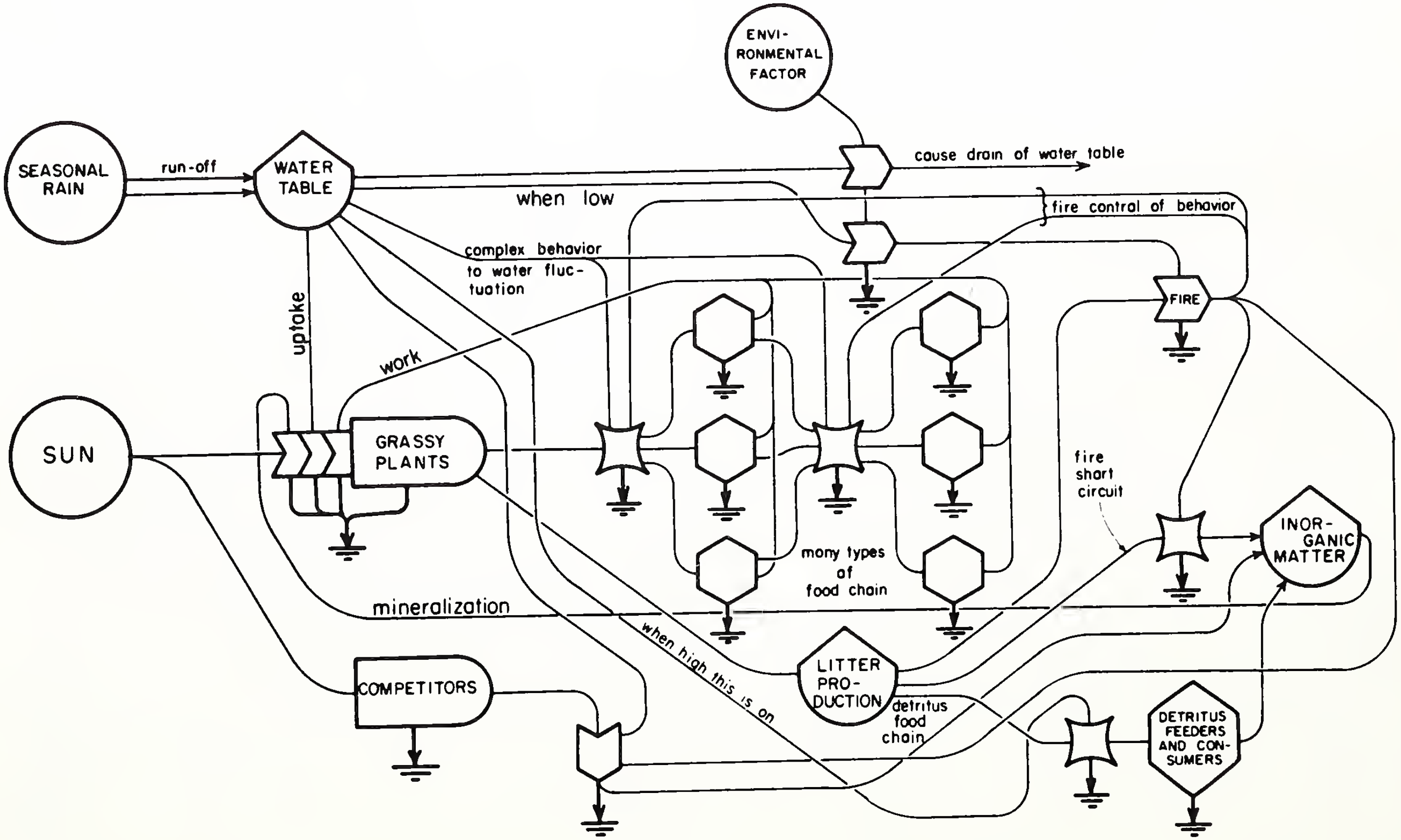


Figure 94.-An energy diagram of a prairie ecosystem.

is growth occurs when there is sufficient water for simultaneous uptake. (Compare this nction in the prairie with the similar function in a granite outcrop - figure 37). Without re, the process of mineralization is slow as it must be broken down through the respiratory tivities of decomposers, detritivores and their consumers. This occurs during high water en the system is functioning as an aquatic ecosystem; the detritus pathway is similar to at described in figures 16 and 17. As shown, this subsystem is only functional during high ter.

In other sections we have introduced the concept of eutrophication (over-enrichment) and normal aging processes of water bodies such as ponds and lakes. The aging process is uitable with the filling in of a water body; a process whose rate is increased by eutro- ication. Through sediment buildup the water body becomes shallower and shallower until oted emergents cover the water surface. As it fills in further the water body becomes a marsh and eventually a prairie which is sometimes wet and sometimes dry depending on the infall. This process of ecosystem development takes hundreds or thousands of years and uld culminate in a forest were it not for fire. During the dry periods, the system is pable of burning and burns frequently. Thus, the species of plants which are capable of viving in the system are those which are adapted to both fire and inundation. In the rgy model, fire and a high water table are shown stressing those non-adapted species which uld ultimately become the dominants in the system. You may have already guessed it by now, this system is very sensitive to man's well-intentioned efforts at draining the landscape protecting it from fire.

cypress dome ecosystems

Again we draw our attention to the cypress domes, not because they occur in the Ocala ional Forest but rather because they represent a common Florida ecosystem and one whose avior is indicative of some unique functions. Thus, it is worthy of a few words.

The cypress dome sits on a perched water table held in an elevated position by a water ermeable lens. In the diagram (figure 95), the water-filled lens is indicated by the outline. Within it are the major producers which include the cypress, a periferal under- ry of various woody species and thick layers of moss. Each is powered by the sun with ductivity being controlled through a workgate by the amount of available nutrients. Be- se the woody understory species are located around the perifery of the dome they must pete with the surrounding vegetation (shown with a negative multiplier). The available rients are maintained by: (1) the system's decomposers, (2) the nutrients in rain, (3) off from surrounding areas, (4) the recycling activities of resident and external consumers, , (5) the occassional dry-season fire which quickly converts organic matter to a mineral- h ash. Because of the usually moist conditions within the dome, consumers in the adjacent systems find food, water, and cover during periods of stress, such as fire which seldom pletely burns the dome. The outside consumers are shown coupled to the dome through these ctions. In effect, the dome serves as a survival reservoir for species to re-colonize adjacent ecosystem after, for instance, a fire. Without this source of new individuals process of recovery would be much slower. The major food sources for both resident and nsient consumers are the understory species whose dominance is controlled by the more ndant cypress. This is controlled primarily through shading.

The amount of water in the dome has several major influences which contribute to the racteristic behavior of the dome ecosystem. Water which enters the system only drains y during periods when the water level is very high, and, when it does, it carries with dissolved organic matter. The primary mechanism for water loss is through evapotrans- ation (eT) which is illustrated as being powered by dry air subject to the availability water for evaporation. The negative workgate being controlled by the moss mat retards s loss through the moss's ability to hold water like a sponge. The constant input of rients, primarily in water, coupled with a greater loss of water than nutrients means t the total nutrient stock increases over time. This net increase occurs through the lowing mechanisms: the cypress and understory trees take up nutrients which are bound

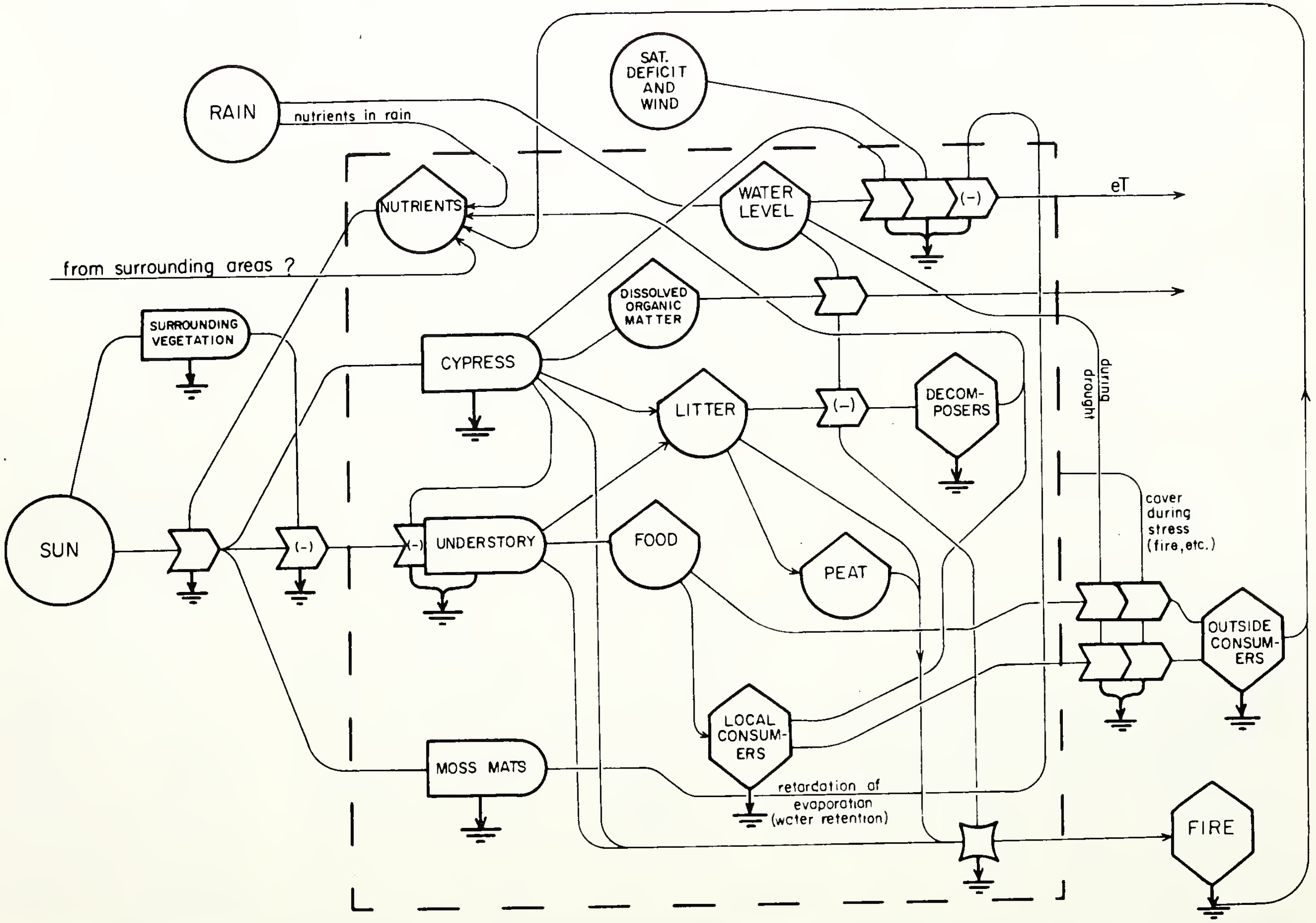


Figure 95.-An energy diagram of a cypress dome ecosystem.

in organic matter. A portion is tied up in the structure of the trees and the remainder is recycled in the form of litter fall or is biologically exported through outside consumers. When water covers the litter, aerobic decomposition appreciably slows (negative workgate) and the litter is stored as peat. When the water level is low, aerobic respiration recycles the minerals back to the producers. The net increase in nutrients in the dome (mentioned previously) can be accounted for in the buildup of organic peat. This, of course, increases the water holding capacity of the system. During long periods of low rainfall, however, the peat dries out and will burn should fire enter the dome; usually, just the litter layer burns. Fires which completely destroy a cypress dome rarely occur except during extreme droughts. Man, however, has increased the probability of such fires by lowering the water table over large areas through land drainage.

The aquatic ecosystem

In Chapter VI, the discussion of the aquatic communities of the Ocala National Forest focused on the tremendous variety of types and components within types. To develop a generic energy model which encompasses this diversity would be almost meaningless. Thus, to summarize the structure and function of an aquatic system and discuss its behavior, a model of a small, freshwater stream has been prepared (figure 96). This diagram lumps the components into major functional groupings and like the other models, omits the detail not pertinent to the major flows of energy.

The water level of a stream represents a balance of all inputs (rain, runoff, springs, etc.) minus all outputs (stream discharge, percolation, evapotranspiration, etc.) and, of course, is the medium of the aquatic system. This is shown as an amplifier on the system; the system expands and contracts relative to water level. Other amplifiers on the flow of solar energy include: (1) the carbon dioxide and minerals required in production, (2) temperature as a regulator of respiration, and (3) additions of limiting minerals resulting from man's activities. Whereas cultural eutrophication is not a forcing function in nature without man, it is so common in Florida and in the region of the Ocala National Forest, that it must be considered as a component of our environment. In aquatic environments such as occur in Florida, temperature, carbon dioxide and water level are usually at optimum levels, which means that the rate of production is controlled by the nutrient availability. Thus, it is the input of nutrients from domestic wastes, land clearing and drainage and fertilizer runoff that invariably increase net production; the manifestation of eutrophication.

The major producer components include floating, submerged (rooted) and attached plants (periphyton). As shown in the diagram (two negative workgates), there are two major forms of interactions among these plant forms. Floating plants such as hyacinths and water lettuce may cover the water surface to the extent that sunlight cannot penetrate down to the submerged species. The negative workgate illustrates this reduction in supporting energies which lead to the eventual elimination of the submerged rooted species. In nutrient-poor waters, however, the submerged and attached forms may reduce the energies available to the floating forms. This occurs through the ability of the non-floating forms to utilize nutrients more effectively and thus successfully compete with floating plants. The competitive advantage accrues to the rooted and attached plants because they also have access to nutrients in the sediments.

The diagram shows that the net production of the producer populations may flow either through consumers or decomposers acting on accumulated organic matter (detrital sediments). When there is sufficient oxygen to power the respiratory processes, the aerobic consumers and decomposers, these processors remain functional. However, when net production of organic matter is excessive, the oxygen demand for chemical, non-biological, oxidation depletes the oxygen in the water body. This stops the aerobic processes and organic sediments accumulate under anaerobic conditions (see figure 52). This is a very common aquatic system response to eutrophication which of course speeds up the aging process. In streams, however, the normal flushing transports these materials to downstream water bodies where they may either contribute to increased organic sedimentation or under higher oxygen levels be chemically or biologically (respiration) oxidized. Society is currently experimenting with artificial

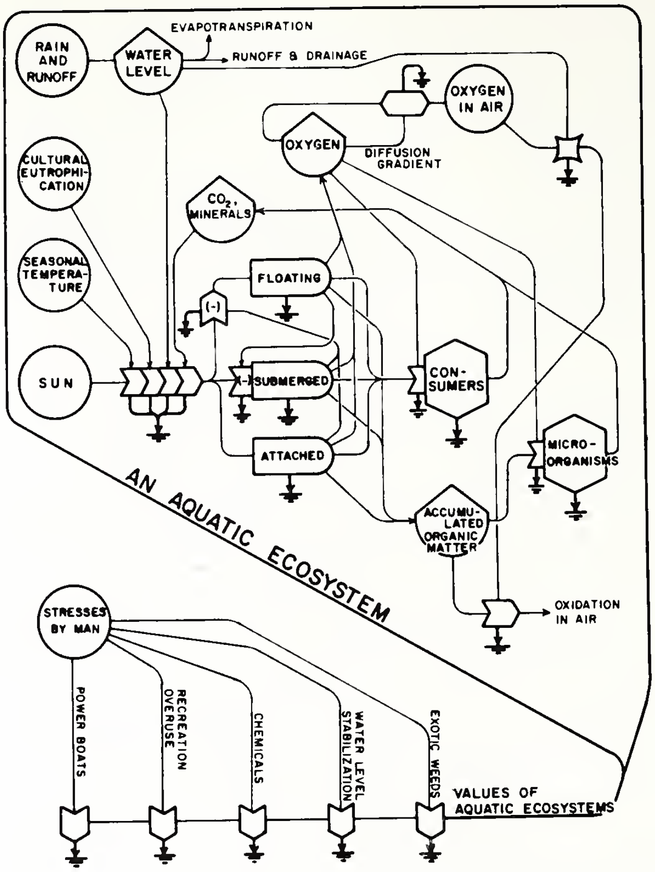


Figure 96.-A generalized energy diagram of an aquatic ecosystem.

awdowns of ponds, lakes, and impoundments to expose the organic sediments to the oxidizing wer of the air. Such techniques may ultimately be successful if: (1) excess nutrient inputs, ich initiated the problem, are stopped, (2) the minerals which remain in the system, after ganic oxidation, are retained in the sediment residue and not allowed to re-enter the water lumn, and, (3) there is a source of plants and animals to re-establish the desired populations.

In the bottom of the diagram (figure 96) there is a summary of the mechanisms by which n detracts from the natural values of the aquatic ecosystem through stress. These include:

(1) Eutrophication which has been discussed.
(2) Exotic weeds which compete with native plant species. Exotic species may quickly dominate an area because the system lacks adaptations for the control of the population sizes.
(3) Water level stabilization serves to either increase or decrease flows. As the ecosystem adapts to this altered forcing function man looses the old preferred values even though new values may be substituted.
(4) Chemicals which include the classical pollutants as well as biocides introduced to control excessive plant growth. Whereas the target species may be temporarily eliminated, the dead organic matter accumulates on the bottom and the nutrients remain in the system.
(5) Recreation overuse contributes to erosion of banks, deterioration of the site and occassionally the elimination of a favored species through say, overfishing.
(6) Power boats create turbulence which may alter banks and shorelines. They are also suggested to contribute pollutants associated with motor operations such as unburned gasoline, oil, metal particles, etc.

mmary

Presented in this Chapter was an ecological interpretation of the Ocala National Forest sed on the concept of the ecosystem. The background for this was developed in the preceed- g chapters which combined ecological principles with local examples. This showed that the osystem is the only self-sustaining, self-designing, and self-perpetuating unit of life on r planet which is capable of supporting life as long as solar energy is available. The esentation of concepts, historical background, geological and climatological interactions d a traditional description of communities and community components provided the foundation r describing that portion of our overall life-support system known as the Ocala National rest. In this final section, we discuss one more model which attempts to show the inter- tions of man and nature in our biosphere. We end this work with this model because it mmarizes the implicit "mood" of the book and because we feel that the public must understand actly what values natural ecosystems offer to man.

In our daily routine of life, we are constantly forced to make decisions that involve e assessment of value and choices between various alternatives. Within this time-frame, always choose that alternative which brings about the greatest and most immediate gain reward to our actions. Indeed, if this were not the case, one would soon find himself the short end of all transactions. In nature, species and communities are also faced with vironmental situations to which they respond with strategies designed for maximum short- rm gain. For example, a predator chasing his prey, or a field of weeds growing after a ring shower. As a civilization however, when we must make decisions, we must also consider other dimension of time and values. Civilizations, like ecosystems, have longer time spans an the individuals that compose them, and for this reason, the thinking and actions that are od for the individual are not necessarily good for the larger system of which he is but one rt. When we speak in terms of civilizations, we are talking about survival as the ultimate iteria of value. Actions which are very logical for short-term gain might well be suicidal the long-term time interval. Thus, if the predator was to eat all his prey in one day, would soon starve to death!

In our current social setting we are in a period of transition in which our values are anging from those of growth and development of the pioneer, successional system, to those the steady-state society of the future. Our current social make-up is an interesting one because it is made up of people of both persuasions and both are convinced that they are right! Some want continued growth while others want stabilization of growth. Caught in the middle of this controversy are the natural ecosystems such as the Ocala National Forest. Their survival depends on our policies. The question is what do we do with them? Are they to be developed and used for the benefit of today's man? Or are they to be protected, and maintained as refuges of biological diversity? The first represents the idea that net value is equal to use, harvest, and demand; while the alternative represents the idea that the natural system has intrinsic value irrespective of man's actual direct use. It is clear that to sustain any kind of civilization we need both kinds of systems, but to this date, no one has ventured into a suggestion of the optimal ratio of yield versus climax systems necessary to maintain the highest quality of human life on this earth. In this book, we have consistently defended the steady-state system and we have suggested that we must utilize as many natural processes and adaptations in our management actions as possible. Only in this way will we be able to lower the cost of management and increase the overall homeostatis (stability) of the planet. This summary will not be an exception to this philosophy. Figure 97 attempts to show the ultimate value of natural ecosystems to man, i.e., their value as life-support systems which are essential for the ultimate survival of our civilization. By life support we mean the control and maintenance of conditions leading to the perpetuation of life within the bioshpere. Our framework focuses on the long-term benefits to our civilization and thus we offer this as a long-term strategy for the management of large natural resources such as the Ocala National Forest.

The model in figure 97 highlights all the natural flows which are doing work for man and thus represent those natural services which are directly responsible for sustaining life on the planet. They include:

(1) Maintenance of the biogeochemical cycles (air, gases, minerals, water) which represent the raw materials of civilizations and of life.

(2) Absorption of the wastes of man which include all the chemicals that we produce and which are absorbed by natural ecosystems. When the public service benefits of intact ecosystems are absent, these substances become dangerous and cause serious threats to our health and survival.

(3) Photosynthetic products which support the biological diversity of the planet.

(4) Climate moderation essential for the control of vital biological processes.

These services are free gifts of nature and are provided mostly by vast areas of natural systems adapted to one another and adapted to the performance of these work functions. These functions are stressed when the diversitites of the ecosystems are reduced and when its processes are stressed by the physical or chemical actions of man. To date, we have taken these life support functions so much for granted that they may even sound trivial to the reader. If we consider the acceleration of human intrusion into these vital processes of nature (man as a geological factor, for instance), one wonders however, when will we reach the the threshhold point where we change conditions beyond the limits of our own adaptations to survive and those of the environment's capacity to sustain us.

We thus end this book with a word of caution and some hope for optimism. Let's use nature, recreate in nature, and let's enjoy her beauty and services. She can take a lot of punishment, and will recover through the process of succession. However, let's also understand nature so that we can carefully estimate her limits and plan our actions accordingly.

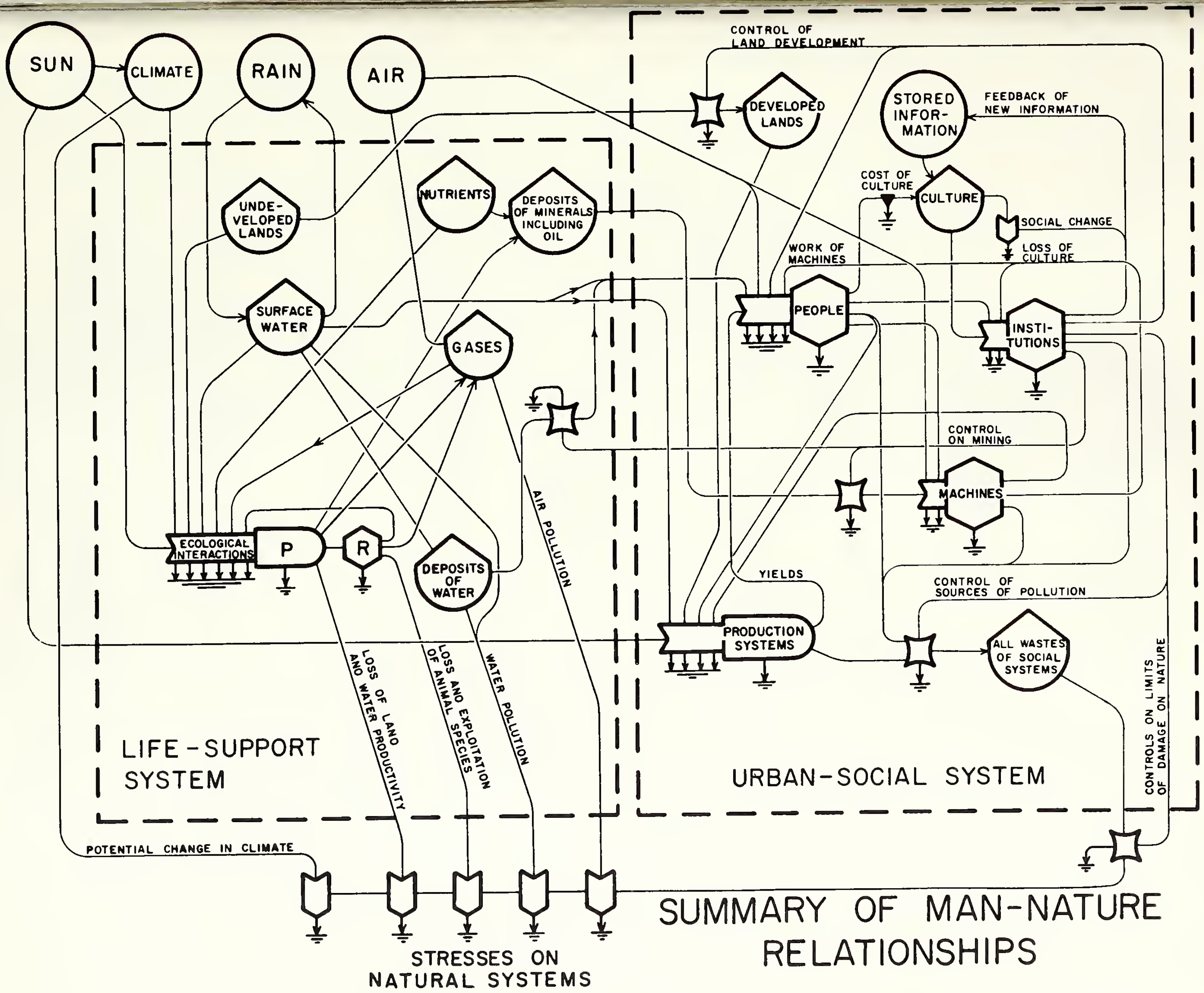

SUN
CLIMATE
RAIN
AIR
UNDE-VELOPED LANDS
SURFACE WATER
NUTRIENTS
DEPOSITS OF MINERALS INCLUDING OIL
GASES
ECOLOGICAL INTERACTIONS
P
R
DEPOSITS OF WATER
AIR POLLUTION
WATER POLLUTION
LOSS AND EXPLOITATION OF ANIMAL SPECIES
LOSS OF LAND AND WATER PRODUCTIVITY
POTENTIAL CHANGE IN CLIMATE
LIFE-SUPPORT SYSTEM
STRESSES ON NATURAL SYSTEMS
CONTROL OF LAND DEVELOPMENT
DEVELOPED LANDS
STORED INFOR-MATION
FEEDBACK OF NEW INFORMATION
COST OF CULTURE
CULTURE
SOCIAL CHANGE
LOSS OF CULTURE
WORK OF MACHINES
PEOPLE
INSTI-TUTIONS
CONTROL ON MINING
MACHINES
YIELDS
CONTROL OF SOURCES OF POLLUTION
PRODUCTION SYSTEMS
ALL WASTES OF SOCIAL SYSTEMS
CONTROLS ON LIMITS OF DAMAGE ON NATURE
URBAN-SOCIAL SYSTEM
SUMMARY OF MAN-NATURE RELATIONSHIPS

Figure 97.-An energy diagram summarizing man-nature relationships.

APPENDIX

A CHECKLIST OF THE ANIMALS OF THE OCALA NATIONAL FOREST

The number of animal species which are components of the ecosystems of the Ocala National Forest is so large that individual descriptions are beyond the scope of this book. However, because a checklist of animal species is generally unavailable, a listing of the vertebrates is included here. The list includes all species which have either been reported to occur in the Ocala National Forest in the literature or whom specialists have observed. The many people who cooperated in the preparation of this checklist are graciously included in the Acknowledgements.

AMPHIBIANS

Flatwoods or frosted salamander - *Ambystoma cingulatum*
Marbled salamander - *A. opacum*
Mole salamander - *A. talpoideum*
Tiger salamander - *A. tigrinum*
Two-toed amphiuma - *Amphiuma means*
Striped newt - *Notophthalmum perstriatus*
Common newt - *N. viridescens*
Dusky salamander - *Desmognathus fuscus*
Slimy salamander - *Plethodon glutinosus*
Rusty mud salamander - *Pseudotridon montanus*
Dwarf salamander - *Manculus quadridigitatus*
Dwarf siren - *Siren intermedia*
Great siren - *S. lacertina*
Mud siren - *Pseudobranchus striatus*
Eastern spadefoot - *Scaphiopus holbrooki*
Oak toad - *Bufo quercicus*
Southern toad - *B. terrestris*
Greenhouse frog - *Eleutherodactylus planirostris*
Cricket frog - *Acris gryllus*
Green tree frog - *Hyla cinerea*
Spring peeper - *H. crucifer*
Piney woods tree frog - *H. femoralis*
Barking tree frog - *H. gratiosa*
Least tree frog - *H. ocularis* (also known as *Limnaoedus ocularis*)
Squirrel tree frog - *H. squirella*
Common or gray tree frog - *H. versicolor*
Chorus frog - *Pseudacris nigrita*
Ornate chorus frog - *P. ornata*
Crawfish frog - *Rana areolata*
Bullfrog - *R. catesbeiana*
Green frog - *R. clamitans*
Pig frog - *R. grylio*
River frog - *R. heckscheri*
Leopard frog - *R. pipiens*
Eastern narrow-mouthed toad - *Gastrophyrne carolinensis*

REPTILES

Snapping turtle - *Chelydra serpentina*
Alligator snapping turtle - *Macroclemys temmincki*
Striped mud turtle - *Kinosternon bauri*
Mud turtle - *K. subrubrum*
Stinkpot - *Sternothaerus odoratus*
Loggerhead musk turtle - *S. minor*

Spotted turtle - *Clemmys guttata*
Box turtle - *Terrapene carolina*
Cooter - *Pseudemys floridana*
Florida red-bellied turtle - *P. nelsoni*
Pond slider or ground slider - *P. scripta*
Chicken turtle - *Deirochelys reticularia*
Gopher tortoise - *Gopherus polyphemus*
Spiny softshell - *Trionyx ferox*
American alligator - *Alligator mississipiensis*
Green anole or common "chameleon" - *Anolis carolinensis*
Eastern fence lizard - *Sceloporus undulatus*
Florida scrub lizard - *S. woodi*
Slender glass lizard - *Ophisaurus attenuatus*
Island glass lizard - *O. compressus*
Eastern glass lizard - *O. ventralis*
Six-lined racerunner - *Cnemidophorus sexlineatus*
Florida red-tailed skink - *Eumeces egregius*
Southeastern five-lined skink - *E. inexpectatus*
Broad-headed skink - *E. laticeps*
Brown or ground skink - *Lygosoma laterale*
Sand skink - *Neoseps reynoldsi*
Florida worm lizard - *Rhineura floridana*
Rainbow snake - *Abastor erythrogrammus*
Scarlet snake - *Cemophora coccinea*
Black snake or Racer - *Coluber constrictor*
Eastern ring-necked snake - *Diadophis punctatus*
Indigo snake - *Drymarchon corais*
Corn snake - *Elaphe guttata*
Rat snake or Chicken snake - *Elaphe obsoleta*
Mud snake - *Farancia abacura*
Rough earth snake - *Haldea striatula*
Smooth earth snake - *H. valeriae*
Eastern hog-nosed snake - *Heterodon platyrhinos*
Southern hog-nosed snake - *H. simus*
Prairie kingsnake - *Lampropeltis calligaster*
Scarlet kingsnake or Milk snake - *L. soliata*
Common kingsnake - *L. getulus*
Striped swamp snake - *Liodytes alleni*
Coachwhip snake - *Masticophis flagellum*
Diamondback rattlesnake - *Cortalus adamanteus*
Worm snake - *Carphophis amoenus amoenus*
Coral snake - *Micrurus fulvius*
Green water snake - *Natrix cyclopion*
Banded water snake - *N. fasciata*
Striped water snake or Glossy water snake - *N. rigida*
Common water snake - *N. sipedon*
Brown water snake - *N. taxispilota*
Keeled or rough green snake - *Opheodrys aestivus*
Pine snake - *Pituophis melanoleucas*
Yellow-lipped snake - *Rhadinea flavilata*
Black swamp snake - *Seminatrix pygaea*
Short-tailed snake - *Stilosoma extenuatum*
Brown snake - *Storeria dekayi*
Red-bellied snake - *S. occipitomaculata*
Crowned snake - *Tantilla coronata*
Ribbon snake - *Thamnophis sauritus*
Common garter snake - *T. sirtalis*
Cottonmouth water moccasin - *Agkistrodon piscivorus*
Canebrake rattlesnake - *Crotalus horridus*
Pigmy rattlesnake - *Sistrurus miliarius*

BIRDS

Common loon - *Gavia immer*
Horned grebe - *Podiceps auritus*
Pied-billed grebe - *Podilymbus podiceps*
White-tailed trophic bird - *Phaethon lepturus*
Brown pelican - *Pelecanus occidentalis*
Double-crested cormorant - *Phalacrocorax auritus*
Anhinga or American darter - *Anhinga anhinga*
Great blue heron - *Ardea herodias*
American bittern - *Botaurus lentiginosus*
Cattle egret - *Bubulcus ibis*
Green heron - *Butorides virescens*
Common egret - *Casmerodius albus*
Little blue heron - *Florida caerulea*
Louisiana heron - *Hydranassa tricolor*
Least bittern - *Ixobrychus exilis*
Snowy egret - *Leucophoyx thula*
Black-crowned night heron - *Nycticorax nicticorax*
Yellow-crowned night heron - *N. violacea*
Wood ibis - *Mycteria americana*
White ibis - *Eudocimus albus*
Glossy ibis - *Plegadis falcinellus*
Canada goose - *Branta canadensis*
Blue goose - *Chen caerulescens*
Fulvous tree-duck- *Dendrocygna bicolor*
Pintail - *Anas acuta*
Green-winged teal -*A. carolinensis*
Cinnamon teal - *A. cyanoptera*
Blue-winged teal - *A. discors*
Mottled duck - *A. fulvigula*
Mallard - *A. platyrhynchos*
Black duck - *A. rubripes*
Gadwall - *A. strepera*
Wood duck - *Aix sponsa*
Baldpate - *Mareca americana*
European widgeon - *M. penelope*
Shoveler - *Spatula clypeata*
Lesser scaup - *Aythya affinis*
Redhead - *A. americana*
Ring-necked duck - *A. collaris*
Greater scaup - *Aythya marila*
Canvasback - *A. valisineria*
Bufflehead - *Bucephala albeola*
Common Goldeneye - *B. clangula*
White-winged scoter - *Melanitta deglandi*
Ruddy duck - *Oxyura jameicensis*
Hooded merganser - *Lophodytes cucullatus*
Red-breasted merganser - *Mergus serrator*
Turkey vulture - *Cathartes aura*
Black vulture - *Coragyps atratus*
Swallow-tailed kite - *Elanoides forficatus*
Mississippi kite - *Ictinia mississippiensis*
Cooper's hawk - *Accipiter cooperi*
Sharp-shinned hawk - *A. striatus*
Short-tailed hawk - *Buteo brachyurus*
Red-tailed hawk - *B. jamaicensis*
Rough-legged hawk - *B. lagopus*

Red-shouldered hawk - *Buteo lineatus*
Broad-winged hawk - *B. platypterus*
Bald eagle - *Haliaeetus leucocephalus*
Marsh hawk or harrier - *Circus cyaneus*
Osprey - *Pandion haliaetus*
Pigeon hawk - *Falco columbarius*
Peregrine falcon - *F. peregrinus*
Sparrow hawk - *F. sparverius*
Bobwhite - *Colinus virginianus*
Turkey - *Meleagris gallopavo*
Sandhill crane - *Grus canadensis*
Limpkin - *Aramus guarauna*
American coot - *Fulica americana*
Common gallinule - *Gallinula chloropus*
Black rail - *Laterallus jamaicensis*
Purple gallinule - *Porphyrula martinica*
Sora - *Porzana carolina*
King rail - *Rallus elegans*
Virginia rail - *R. limicola*
Killdeer - *Charadrius vociferus*
Golden plover - *Pluvialis dominica*
Spotted sandpiper - *Actitis macularia*
Upland plover - *Bartramia longicauda*
Wilson's snipe - *Capella gallinago*
Willet - *Catopterophorus semipalmatus*
Semipalmated sandpiper - *Ereunetes pusillus*
White-rumped sandpiper - *Erolia fuscicollis*
Pectoral sandpiper - *E. melanotos*
Least sandpiper - *E. minutilla*
Dowitcher - *Limnodromus griseus*
Greater yellowlegs - *Totanus melanoleucus*
Solitary sandpiper - *Tringa solitaria*
Black-necked stilt - *Himantopus mexicanus*
American avocet - *Recurvirostra americana*
Herring gull - *Larus argentatus*
Laughing gull - *L. atricilla*
Ring-billed gull - *L. delawarensis*
Bonaparte's gull - *L. philadelphia*
Royal tern - *Thalasseus maximum*
Forster's tern - *Sterna forsteri*
Common tern - *S. Hirundo*
Sooty tern - *S. fuscata*
Black tern - *Chlidonias niger*
Black skimmer - *Rynchops nigra*
Ground dove - *Columbigallina passerina*
Mourning dove - *Zenaidura macroura*
Yellow-billed cuckoo - *Coccyzus americanus*
Black-billed cuckoo - *C. erythropthalmus*
Groove-billed ani - *Crotophaga sulcirostris*
Barn owl - *Tyto alba*
Great Horned owl - *Bubo virginianus*
Screech owl - *Otus asio*
Burrowing owl - *Speotyto cunicularia*
Barred owl - *Strix varia*
Chuck-will's widow - *Caprimulgus carolinensis*
Whip-poor-will - *C. vociferus*

Nighthawk - *Chordeiles minor*
Chimney swift - *Chaetura pelagica*
Ruby-throated hummingbird - *Archilochus colubris*
Belted kingfisher - *Megaceryle alcyon*
Red-bellied woodpecker - *Centurus carolinus*
Flicker - *Colaptes auratus*
Red-cockaded woodpecker - *Dendrocopos borealis*
Downy woodpecker - *D. pubescens*
Hairy woodpecker - *D. villosus*
Pileated woodpecker - *Hylatomus pileatus*
Red-headed woodpecker - *Melanerpes erythrocephalus*
Yellow-bellied sapsucker - *Sphyrapicus varius*
Wood peweee - *Contopus virens*
Acadian flycatcher - *Empidonax virescens*
Creasted flycatcher - *Myiarchus crinitus*
Vermilion flycatcher - *Pyrocephalus rubinus*
Phoebe - *Sayornis phoebe*
Gray kingbird - *Tyrannus dominicensis*
Western kingbird - *Tyrannus tyrannus*
Eastern kingbird - *Tyrannus verticalis*
Barn swallow - *Hirundo rustica*
Tree swallow - *Tridoprocne bicolor*
Cliff swallow - *Petrochelidon pyrrhonta*
Purple martin - *Progne subis*
Rough-winged swallow - *Stelgidopteryx ruficollis*
Scrub jay - *Aphelocoma coerulescens*
Common crow - *Corvus brachyrhynchos*
Fish crow - *C. ossifragus*
Blue jay - *Cyanocitta cristata*
Tufted titmouse - *Parus bicolor*
Carolina chickadee - *P. carolinensis*
Red-breasted nuthatch - *Sitta canadensis*
White-breasted nuthatch - *S. carolinensis*
Brown-headed nuthatch - *S. pusilla*
Brown creeper - *Certhia familaris*
Short-billed marsh wren - *Cistothorus platensis*
Long-billed marsh wren - *Telmatodytes palustris*
Carolina wren - *Thryothorus ludovicianus*
Winter wren - *Troglodytes aedon*
House wren - *T. troglodytes*
Catbird - *Dumetella carolinensis*
Mockingbird - *Mimus polyglottos*
Brown thrasher - *Toxostoma rufum*
Veery - *Hylocichla fuscescens*
Hermit thrush - *H. guttata*
Gray-cheeked thrush - *H. minima*
Wood thrush - *H. mustelina*
Eastern bluebird - *Sialia sialis*
Robin - *Turdus migratorius*
Blue-gray gnatcatcher - *Polioptila caerulea*
Ruby-crowned kinglet - *Regulus calendula*
Golden-crowned kinglet - *R. satrapa*
Water pipit - *Anthus spinoletta*
Cedar waxwing - *Bombycilla cedrorum*
Loggerhead shrike - *Lanius ludovicianus*

Starling - *Sturnus vulgaris*
Yellow-throated vireo - *Vireo flavifrons*
White-eyed vireo - *V. griseus*
Red-eyed vireo - *V. olivaceus*
Solitary vireo - *V. solitarius*
Black-throated blue warbler - *Dendroica caerulescens*
Myrtle warbler - *D. coronata*
Prairie warbler - *D. discolor*
Yellow-throated warbler - *D. dominica*
Magnolia warbler - *D. magnolia*
Palm warbler - *D. palmarum*
Yellow warbler - *D. petechia*
Pine warbler - *D. pinus*
Blackpoll warbler - *D. striata*
Cape May warbler - *D. tigrina*
Common yellowthroat - *Geothylpis trichas*
Worm-eating warbler - *Helmitheros vermivorus*
Yellow-breasted chat - *Icteria virens*
Swainson's warbler - *Limnothlypis swainsonii*
Black and white warbler - *Mniotilta varia*
Parula warbler - *Parula americana*
Prothonotary warbler - *Protonotaria citrea*
Ovenbird - *Seiurus aurocapillus*
Louisiana waterthrush - *S. motacilla*
Northern waterthrush - *S. noveboracensis*
American Redstart - *Setophaga ruticilla*
Orange-crowned warbler - *Vermivora celata*
Tennessee warbler - *V. peregrina*
Hooded warbler - *Wilsonia citrina*
House or English sparrow - *Passer domesticus*
Red-winged blackbird - *Agelaius phoeniceus*
Boat-tailed grackle - *Cassidix mexicanus*
Bobolink - *Dolichonyx orizivorus*
Brewer's blackbird - *Euphagus carolinus*
Rusty blackbird - *Euphagus cyanocephalus*
Bullock's oriole - *Icterus bullockii*
Baltimore oriole - *I. galbula*
Orchard oriole - *I. spurius*
Brown-headed cowbird - *Molothrus ater*
Common grackle - *Quiscalus quiscula*
Eastern meadowlark - *Sturnella* magna
Bronzed cowbird - *Tangavius aeneus*
Yellow-headed blackbird - *Xanthocephalus xanthocephalus*
Scarlet tanager - *Piranga olivacea*
Summer tanager - *P. rubra*
Bachman's sparrow - *Aimophila aestivalis*
Grasshopper sparrow - *Ammodromus savannarum*
Purple finch - *Carpodacus purpureus*
Blue grosbeak - *Cuiraca caerulea*
Evening grosbeak - *Hesperiphona vespertina*
Slate-colored junco - *Junco hyemalis*
Swamp sparrow - *Melospiza georgiana*
Song sparrow - *M. melodia*
Savannah sparrow - *Passerculus sandwichensis*
Fox sparrow - *Passerella iliaca*
Leconte's sparrow - *Passerherbulus caudacutus*
Henslow's sparrow - *P. henslowi*
Painted bunting - *Passerina ciris*

Indigo bunting - *P. cyanea*
Rose-breasted grosbeak - *Pheucticus ludovicianus*
Black-headed grosbeak - *P. melanocephalus*
Rufous-sided towhee - *Pipilo erythrophthalmus*
Vester sparrow - *Pooecetes gramineus*
Cardinal - *Richmondena cardinalis*
Pine siskin - *Spinus pinus*
American goldfinch - *S. tristis*
Clay-colored sparrow - *Spizella pallida*
Chipping sparrow - *S. passerina*
Field sparrow - *S. pusilla*
White-throated sparrow - *Zonotrichia albicollis*
White-crowned sparrow - *Z. leucophrys*

MAMMALS

Opossum - *Didelphis marsupialis*
Short-tailed shrew - *Blarina brevicauda*
Least shrew - *Cryptotis parva*
Long-nosed shrew - *Sorex longirostris*
Eastern mole - *Scalopus aquaticus*
Florida yellow bat - *Dasypterus floridanus*
Big brown bat - *Eptesicus fuscus*
Red bat - *Lasiurus borealis*
Hoary bat - *L. cinereus*
Eastern yellow bat - *L. intermedius*
Seminole bat - *L. seminolus*
Southeastern bat or Florida brown bat - *Myotis austroriparius*
Evening bat - *Mycticeius humerialis*
Big-eared bat - *Plecotus rafinesquii* (also known as *Corynorhinus rafinesquii* - Lump-nosed bat)
Eastern pipistrelle - *Pipistrellus subflavus*
Freetail bat - *Tadarida brasiliensis* (also known as *T. cynocephala*. Florida freetail)
Nine-banded armadillo - *Dasypus novemcinctus*
Eastern cottontail - *Sylvilagus floridanus*
Marsh rabbit - *S. palustris*
Flying squirrel - *Glaucomys volans*
Gray squirrel-*Sciurus carolinensis*
Fox squirrel - *S. niger*
Pineywoods gopher - *Geomys pinetis*
Pine vole - *Microtus pinetorum*
Florida water rat or Round-tailed muskrat - *Neofiber alleni*
Florida woodrat - *Neotoma floridana*
Rice rat - *Oryzomys palustris*
Florida deer mouse - *Peromyscus floridanus*
Cotton mouse - *P. gossypinus*
Golden mouse - *P. nuttalli* (also known as *Ochrotomys nuttalli*)
Beach mouse - *P. polionotus*
Eastern harvest mouse - *Reithrodontomys humulis*
Cotton rat - *Sigmodon hispidus*
House mouse - *Mus musculus*
Norway rat - *Rattus norvegicus*
Black rat or Roof rat - *R. rattus*
Coyote - *Canis latrans*
Gray fox - *Urocyon cinereoargenteus*
Red fox - *Vulpes fulva*

Black bear - Ursus americanus
Racoon - Procyon lotor
River otter - Lutra canadensis
Striped skunk - Mephitis mephitis
Long-tailed weasel - Mustela frenata
Mink - Mustela vison
Eastern spotted skunk - Spilogale putorius
Mountain lion - Felis concolor coryeii
Bobcat - Lynx rufus
West Indian manatee - Trichechus manatus
European wild boar or Razorback hog - Sus scrofa
Whitetail deer - Odocoileus virginianus

FISHES

Sea lamprey - Petromyzon marinus
Atlantic sting ray - Dasyatis sabina
Southern sting ray - D. americana
Atlantic sturgeon - Acipenser oxyrhynchus
Shortnose sturgeon - A. brevirostrom
Longnose gar - Lepisosteus osseus
Florida gar - L. platyrhincus
Bowfin - Amia calva
Tarpon - Megalops atlantica
American eel - Anguilla rostrata
Gizzard shad - Dorosoma cepedianum
Threadfin shad - D. petenense
Yellowfin menhaden - Brevoortia smithi
Blueback herring - Alosa aestivalis
American shad - A. sapidissima
Hickory shad - A. mediocris
Scaled sardine - Harengula pensacolae
Atlantic thread herring - Opisthonema oglinum
Bay anchovy - Anchoa mitchilli
Striped anchovy - Anchoa hepsetus
Eastern mudminnow - Umbra pygmaea
Chian pickerel - Esox niger
Redfin pickerel - E. americanus
Golden shiner - Notemigonus crysoleucas
Pugnose minnow - Notropis emiliae
Salfin shiner - N. hypselopterus
Tailight shiner - N. maculatus
Dusky shiner - N. cummingsae
Coastal shiner - N. petersoni
Ironcolor shiner - N. chalybaeus
Bluenose shiner - N. walaka
Redeye chub - N. harperi
Lake chubsucker - Erimyzon sucetta
White catfish - Ictalurus catus
Channel catfish - Ictalurus punctatus
Snail bullhead - I. brunneus
Yellow bullhead - I. natalis
Brown bullhead-I. nebulosus
Tadpole madtom - Noturus gyrinus
Speckled madtom - N. ledtacanthus
Gafftopsail catfish - Bagre marinus
Sea catfish - Galeichthys felis

Pirate perch - *Apredoderus sayanus*
Atlantic needlefish - *Strongylura marina*
Bluefin killifish - *Lucania goodei*
Pygmy killifish - *Leptolucania omnata*
Rainwater killifish - *Lucania parva*
Seminole killifish - *Fundulus seminolis*
Marsh killifish - *F. confluentus*
Golden topminnow - *F. chrysotus*
Banded topminnor - *F. cingulatus*
Lined topminnow - *F. lineolatus*
Flagfish - *Jordanella floridae*
Variegated pupfish - *Cyprinodon variegatus*
Lake Eustis pupfish - *Cyprinodon hubbsi*
Salfin molly-*Poecilia latipinna*
Mosquitofish - *Gambusia affinis*
Least killifish - *Heterandria formosa*
Brook silverside - *Labidesthes sicculus*
Tidewater silverside - *Menidia beryllina*
Rough silverside - *Membras martinica*
Gulf pipefish - *Syngnathus scovelli*
Snook - *Centropomus undecimalis*
Striped bass - *Morone saxatilis*
Banded pigmy sunfish - *Ellassoma zonatum*
Everglades pigmy sunfish - *E. evergladei*
Okefenokee pigmy sunfish - *E. okefenokee*
Largemouth bass - *Micropterus salmoides*
Warmouth - *Lepomis gulosus*
Bluegill - *L. macrochirus*
Spotted sunfish - *L. punctatus*
Redear sunfish - *L. microlophus*
Redbreast - *L. auritus*
Dollar sunfish - *L. marginatus*
Blackbanded sunfish - *Enneacanthus chaetodon*
Banded sunfish - *Enneacanthus obesus*
Bluespotted sunfish - *E. gloriosus*
Mud sunfish - *Acantharchus pomotis*
Black crappie - *Pomoxis nigromaculatus*
Flier - *Centrarchus macropterus*
Blackband darter - *Percina nigrofasciata*
Brown darter - *Etehostoma edwini*
Swamp darter - *E. fusiforme* barratti
Tessellated darter - *E. olmstedi*
Crevalle jack - *Caranx hippos*
Gray snapper - *Lutjanus griseus*
Irish pompano - *Diapterus olisthostomus*
Spotfin mojarra - *Eucinostomus argenteus*
Sheepshead - *Archosargus probatocephalus*
Pinfish - *Logodon rhomboides*
Spotted sea trout - *Cynoscion nebulosus*
Red drum - *Sciaenops ocellata*
Atlantic croaker - *Micropogon undulatus*
Silver perch - *Bairdiella chrysura*
Spot - *Leiostomus xanthurus*
Mountain mullet - *Agonostomus monticola*
White mullet - *Mugil curema*

Striped mullet - *Mugil cephalus*
Fat sleeper - *Dormitator maculatus*
River goby - *Awaous taiasica*
Largemouth goby - *Microgobius gulosus*
Naked goby - *Gobiosoma bosci*
Code goby - *Gobiosoma robustum*
Darter goby - *Bogionellus boleosoma*
Freshwater goby - *Bogionellus shufeldti*
Violet goby - *Gobiodes brousonneti*
Southern flounder - *Paralichthys lethostigma*
Bay whiff - *Citharichthys spilopterus*
Hogchoker - *Trinectes maculatus*

GLOSSARY

abiotic - non living
aquifer - a porous geological material through which water flows
aquiclude - a non-porous stratum restricting water flow to the aquifer
biogeochemical cycles - the flow of chemical elements in the biosphere
biomass - the amount of organic matter, usually expressed as weight per unit area
biosphere - the earth volume containing life
biotic - living
calcareous - containing calcium carbonate ($CaCO_3$) such as limestone
calorie - the amount of energy needed to raise the temperature of one gram of water one degree centigrade
carrying capacity - the optimum population size which an area can support during the mos critical period of the year
climax - the end product of succession, i.e., the steady-state ecosystem
compartment - any component of an ecosystem identified by an input, a storage and an output
decomposer - an organism, usually bacteria and fungi, which breaks down detritus into simplier compounds
detritus - non-living organic matter such as dead organisms and worn-out plant parts
diversity - a measure of the different kinds of things in an area, for instance, the number of species per 1000 individuals
echelon fault - a steplike formation of faults
ecology - the study of ecosystem structure and function
ecosystem - the smallest unit of life which is self-maintaining, self-reproducing and self-designing
ecosystem manager - an organism which utilizes a very small fraction of the total energy of a system and in return provides a service which contributes to the survival of the system
ecotone - the transition zone between two communities
efficiency - the ratio of useful work performed per unit of energy used; always less tha 100%
endemic - restricted to a specific area
energy - the capacity to do work, usually measured in calories in ecology
environment - the sum total of all the external conditions which may influence an organi
eutrophication - over-enrichment, such as the introduction of excess mineral nutrients into a water which stimulates productivity
fault - the line along which two rock surfaces have moved
feedback - a portion of the output which feeds back into the input; a stabilizer
food chain - a specific sequence of potential-energy flow through the organisms of an ecosystem
food web - all potential-energy flows in an ecosystem
forcing function - any energy source which drives an ecosystem
habitat - the observed appearance of an organism's surroundings
horst - an elevated mass of rocks between two faults
hydrology - the study of the storage and movement characteristics of water in the biosph
interglacial - the time period during the Ice Ages between the advance and retreat of th polar ice masses
joint - the crack in a broken rock mass; if the two broken masses move against one anoth a fault is created
kaolinite - a kind of clay
karst topography - the topography created on soluble rock such as limestone; disolving of the limestone creates sinkholes, solution channels and subsurface rivers
leaf area index - the amount of photosynthetic leaf surface per unit area of ground
limiting factor - the single factor which controls a process rate; usually the factor in least supply
littoral - the seashore zone between high and low tide
marl - a mixture of calcium carbonate, clay and sand which crumbles easily

niche - the energetic and mineral role of an organism in an ecosystem
peat - a deposit of partially reduced organic material containing about 60% carbon
peneplain - an extensive geological surface left nearly flat by erosion around the edges
photosynthesis - the biochemical processes which describe the conversion of solar energy into chemical energy
pinnacle - a slender pointed geological formation
population - the total number of individuals of a class within a defined area
power - the rate at which work is performed
producer - any organism capable of converting solar energy into chemical energy; usually a green plant
productivity - the rate at which solar energy is converted to chemical energy; measured as grams organic matter produced per unit area per unit time
public service benefits - the contributions of intact ecosystems to the survival of the larger systems of which man is a part
residence time - the time period that energy or matter occupies a compartment
residual - the elevated rock mass remaining after the surrounding material has eroded away
respiration - the biochemical processes which describe the conversion (oxidation) of chemical energy into work and heat
sedimentary rock - rock formed from the accumulation of other rock fragments, animal or plant remains, or through some process such as evaporation of sea water which leaves a layer of salt behind
shoal - a shallow place in a body of water
siliceous - containing silicon such as sand
sinkhole - results from the collapse of the top of a solution cavern; common in limestone karst areas
stability - a measure of the resistance to change
steady state - a system in which the input equals the output and, thus, there is no change in the internal storage
stress - the drain of energy from an ecosystem
succession - an orderly and directed change which in changes in both the environment and the ecosystem, both undergoing continuous reciprocal influence and adjustment
transpiration - evaporation of water from leaf surfaces
turn-over rate - the time for a given amount of energy or matter to move through a compartment
trophic level - an organism's position in a food chain
work - the exerting of a force against an object

BIBLIOGRAPHY

Alt, D. and H.K. Brooks. 1965. Age of the Florida marine terraces. Journ. Geol. 73:406-411

Anderson, H.W. 1969. Douglas fir region aerial fertilization makes strides in a brief span of years. Forest Inc. 96(11):30-32.

Anonymous. 1968. Florida animal tracks. Florida Game and Fresh Water Fish Commission Series PS 5.

Climatological data, monthly summaries, Florida. U.S. Dept. Commerce, ESSA Weather Bur., Asheville.

1972. Forest trees of Florida. Florida Div. of For., Tallahassee. Tenth Ed. 98

Arata, A.A. 1959. Effects of burning on vegetation and rodent populations in a long leaf pine turkey oak association in north central Florida. Quart. J. Fla. Acad. Sci. 22:94-104.

Armstrong, N.E. and H.T. Odum. 1964. Photoelectric ecosystem. Sci. 143:256-258.

Attiwill, P.M. 1968. The loss of elements from decomposing litter. Ecol. 49:142-145.

Barrington, B.A.,Jr. 1949. Mammals of a north Florida flatwood. Ph.D. Diss., University of Florida, Gainesville.

Bates, M. 1960. *The Forest and the Sea*. Vintage Books, N.Y. 277 pp.

Baumgartner, A. 1965. The heat, water, and carbon dioxide budget of plant cover: Methods an measurement. pp. 495-512. In: Methodology of plant ecophysiology, Proceedings of the Montpelier Symposium.

Beal, F.E.L. 1918. Food habits of the swallows, a family of valuable native birds. U.S. Dep Agr. Bull. 619. 28 pp.

Beckwith, S.L. 1962. Wildgame for recreation in Florida-Prospects for the future. Economic Leaflets 21(4).

Bent, A.C. 1922. *Life History of North American Petrels and Pelican and Their Allies*. Dover Publication, Inc., N.Y. 335 pp.

1926. *Life History of North American Marsh Birds.* Dover Publication, Inc., N.Y. 392 pp.

1927(Part I), 1929(Part II). *Life History of North American Shore Birds*. Dover Publication, Inc., N.Y.

1932. *Life History of North American Gallinaceous Birds*. Dover Publication, Inc. N.Y. 490 pp.

1937(Vol. I), 1938(Vol. II). *Life History of North American Birds of Prey*. Dover Publication, Inc., N.Y. 409 pp.

1939. *Life History of North American Woodpeckers*, Dover Publication, Inc., N.Y. 334 pp.

1942. *Life History of North American Flycatchers, Larks, and Their Allies*. Dover Publication, Inc., N.Y. 555 pp.

1946. *Life History of North American Jays, Crows, and Titmice*. Dover Publication Inc., N.Y. 495 pp.

1947. *Life History of North American Gulls and Terns*. Dodd, Mean and Co., N.Y. 333 pp.

1948. *Life History of North American Nuthatches, Wrens, Thrashers, and Their Allies*. Dover Publication, Inc., N.Y. 475 pp.

1949. *Life History of North American Thrashers, Kinglets, and Their Allies*. Dove Publication, Inc., N.Y. 452 pp.

1950. Life History of North American Wagtails, Shrikes, Vireos, and Their Allies. Dover Publication, Inc., N.Y. 411 pp.

1951. Life History of North American Wildfowl. Dover Publication, Inc., N.Y. Vol. I 224 pp., Vol. II 316 pp.

1953. Life History of North American Warblers.(2 Vols.) Dover Publication, Inc., N.Y. 734 pp.

1958. Life History of North American Blackbirds, Orioles, Tanagers and Allies. Dover Publication, Inc., N.Y. 549 pp.

ermes, B.J., G.W. Leve, and G.R. Tarver. 1963. Geology and groundwater resources of Flagler, Putman, and St. Johns counties, Florida. Fla. Geol. Survey, R.I. No. 32. 97 pp.

ethune, J.E. and J.L. Clutter. 1969. Allocating funds to timber management research. Forest Sci. Monograph No. 16.

eyers, R.J. 1963. Balanced aquatic microcosms-their implications for space travel. Amer. Biol. Tea. 25:422-429.

1964. The microcosm approach to ecosystem biology. Amer. Biol. Tea. 26:491-498.

illings, W.D. 1964. Plants and the Ecosystem. Wadsworth Publ. Co., Belmont, Calif. 154 pp.

lackburn, R.D., P.F. White, and L.W. Weldon. 1968. Ecology of submerged aquatic weeds in south Florida canals. Weed Sci. 16(2):261-266.

lair, W.F. 1964. The case for ecology. BioScience July 17-19.

laisdell, R.S. 1966. The role of Magnolia grandiflora and Fagus grandifolia in forest processes in northwestern Florida. M.S. Thesis, Florida State University, Tallahassee.

olin, B. 1970. The carbon cycle. Scientific Amer., September, pp. 47-57.

ormann, F.H. and G.E. Likens. 1967. Nutrient cycling. Sci. 155:424-429.

radley, W.H. 1966. Tropical lakes, copropel and oil shale. Geol. Soc. Am. Bull. 77:1333-38.

reen, R.S. 1963. Mosses of Florida, An Illustrated Manual. Univ. of Florida Press, Gainesville. 273 pp.

riggs, J.C. 1958. A list of Florida fishes and their distribution. Bull. of the Fla. State Museum. 2(8):252-275.

rock, T.D. 1967. The ecosystem and the steady state. BioScience 17:166-169.

rooks, H.K. 1966. Geological history of the Suwanee River. pp. 37-45. In N. K. Olson (ed.) Miocene-Pliocene series of the Georgia-Florida area. Southeastern Geol. Soc.,Tallahassee.

1967. Rate of solution of limestone in the karst terrane of Florida. Florida Water Resources Research Center, Gainesville, Publ. No. 6. 16 pp.

1968. The Plio-Pleistocene of Florida. pp. 3-42. In: R.D. Perkins (ed.). Late Cenozoic stratigraphy of southern Florida-a reappraisal. Miami Geological Society,Miami.

1970. Geology and physiography of the Oklawaha regional ecosystem. pp. 9-15. In: Environmental impact of the Cross-Florida barge canal. Florida Defenders of the Environment, Gainesville.

Brown, T.W. 1963. The ecology of cypress heads in north-central Florida. M.S. Thesis. University of Florida, Gainesville. 59 pp.

Burt, W.H. and R.P. Grossenheider. 1964. A Field Guide to Mammals. Houghton Mifflin Co., Boston. 284 pp.

Bush, C.S., and J.F. Morton. 1968. Native trees and plants for Florida landscaping. Bull. No. 193, Dept. Agri., State of Florida. 133 pp.

Cahalane, V.H. 1947. Mammals of North America. MacMillan Co., N.Y. 682 pp.

Carr, A.F. 1940. A contribution to the herpetology of Florida. Univ. of Fla. Publ., Biological Series. 3:1-IV:1-118.

1952. Handbook of Turtles. Comstock Publ. Associates, Ithaca, N.Y. 542 pp.

Carr, A.F. and Goin, C.J. 1959. Guide to the Reptiles, Amphibians, and Fresh-Water Fishes of Florida. University of Florida Press, Gainesville. 341 pp.

Carr, M.H. 1965. The Oklawaha River wilderness. The Florida Naturalist. Vol. 38. August.

Clarke, G.L. 1954. Elements of Ecology. John Wiley and Sons, N.Y. 560 pp.

Clewell, A.F. 1971. The vegetation of the Apalachicola National Forest: An ecological perspective. A report submitted to the Office of the Forest Supervisor, Tallahassee, Fla. 152 pp.

Cloudsley-Thompson, J.L. 1967. Microecology. St. Martins Press, N.Y. 48 pp.

Cole, L. 1958. The ecosphere. Scientific Amer. 198(4):83-96.

Collins, E.A., C.D. Monk, and R.H. Spelman. 1964. White-cedar stands in northern Florida. Quart. J. Fla. Acad. Sci. 27:107-110.

Conant, R. 1958. A Field Guide to Reptiles and Amphibians. Houghton Mifflin Co.,Boston 366

Connell, J.H. and E. Orias. 1964. The ecological regulation of species diversity. Amer. Nat 48:399-414.

Cooke, C.W. 1939. Scenery of Florida. Fla. Geol. Survey Bull. 17. 118 pp.

1945. Geology of Florida. Fla. Geol. Survey Bull. 29. 339 pp.

Cooper, R.W. 1951. Is death by fire the only way sand pine can live again? The Southern Lumber Journal. August.

1952. Regeneration problems in sand pine. Southern Lumberman. March.

Cope, E.D. 1888. On the snakes of Florida. Proceedings U.S. National Museum.

Cottam, C. 1965. The ecologists' role in problems of pesticide pollution. BioScience 15: 457-463.

Dasmann, R.F. 1964. African Game Ranching. MacMillan Co., N.Y. 75 pp.

Daubenmire, R.F. 1959. Plants and Environment: A Textbook of Plant Autecology. John Wiley and Sons, N.Y. 422 pp.

1968. Plant Communities: A Textbook of Plant Synecology. Harper and Row, N.Y. 300 pp.

Davis, J.H.,Jr. 1943. The natural features of southern Florida. Florida Geol. Surv. Bull. 25. 311 pp.

1967. General map of natural vegetation of Florida. Florida Agr. Exp. Sta. Circ. S-178.

Deevey, E.S. 1964. General and historical ecology. BioScience. July, pp. 33-35.

de la Cruz, A. and R.G. Wiegert. 1967. 32-phosphorus tracer studies of a horseweed-aphid-an food chain. The Amer. Midl. Nat. 77:501-509.

Demaree, D. 1932. Submerging experiments with taxodium. Ecol. 13:258-262.

Dept. of Game and Fresh Water Fish. 1931. Florida Birds, Quarterly Bulletin of the Dept. of Agriculture, July, 1931, Tallahassee, Fla. 189 pp.

Ditmars, R.L. 1922. The Reptile Book. Doubleday, Page and Co., Garden City, N.Y. 472 pp.

Duncan, W.H. 1970. Endangered rare and uncommon wildflowers found on the southern national forests. U.S. Dept. Agr., Forest Service, Southern Region. 20 pp.

Edmisten, J.E. 1965. Some ecological aspects of pond pine. Bull. Georgia Acad. Sci.23(1) 6

Emery , K.O. and C. O'D. Fselin. 1967. Human food from ocean and land. Sci. 157:1279-1281.

Espenshade, G.H. and C.W. Spencer. 1963. Geology of the phosphate deposits of northern peninsular Florida. U.S. Geol. Survey Bull. 118. 115 pp.

Evans, A.W. 1952. The Cladoniae of Florida. Transactions of the Connecticut Academy of Arts and Sciences. 38:249-336.

Ewel, J. 1969. Spectral solar radiation intensity in two Florida forests. Quart. J. Fla. Acad. Sci. 32:164-170.

Farb, P. 1963. Ecology Time, Inc., N.Y. 192 pp.

Fassett, N.C. 1969. A Manual of Aquatic Plants. University of Wisconsin Press, Madison 405 pp.

Faulkner, G.L. 1970. Geohydrology of the Cross-Florida Barge Canal area with special reference to the Ocala vicinity. Open file report, U.S. Geol. Survey, Tallahassee,Fla. 222 pp.

Ferguson, G.E., C.W. Lingham, S.K. Love, and R.O. Vernon. 1947. Springs of Florida. Fla. Geol. Survey Bull. 31. 196 pp.

Forbush, E.H. and rev. by May, J.B. 1965. Natural History of American Birds of Eastern and Central North America. Bramhall House, N.Y. 552 pp.

Frittz, H.C. 1966. Growth-rings of trees: Their correlation with climate. Sci. 154:973-979.

Frye, D.E. (ed.). 1969. Remarks on the fresh water fishery resources of the St. John's River basin. Florida Game and Fresh Water Fish Commission.

Garcia-Moya, E. and C. M. McKell. 1970. Contribution of shrubs to the nitrogen economy of a desert-wash plant community. Ecol. 51:81-88.

Gardner,G.M., D.Q. Thompson, A.E. Lugo and D.J. Pool (eds.) 1972. An environmental assessment of Lake Ocklawaha-Rodman Reservoir. A Report to the President's Council on Environmental Quality and the Secretary of the Army. Prepared by Dept. of Army, Dept. of Interior and Dept. of Agriculture. 45 pp.

Garth, R.E. 1964. The ecology of Spanish moss (Tillandsia usneoides): its growth and distribution. Ecol. 45:470-481.

Gates, D.M. 1968. Energy exchange in ecology. BioScience 18:90-95.

1968. Towards understanding ecosystems. Advances in Ecol. Res. 5:1-35.

Geiger, R. 1965. The Climate Near the Ground. Harvard University Press, Cambridge, 611 pp.

Geiger,R.K.1967. Accumulation of dead fuel in pine flatwoods for one to ten year periods since burning. M.S. Thesis. University of Florida, Gainesville. 31 pp.

Gessel, S.P., K.J. Turnbull, and F.T. Tremblay. 1960. How to fertilize trees and measure response . National Plant Food Institute. 67 pp.

Golley, F.B. and J.B. Gentry. 1964. Bioenergetics of the sourthern harvester ant Pogonomyrmex badius. Ecol. 45:217-225.

Goodwin, R.H. 1967. The future role of the biologist in protecting our natural resources. BioScience. 17:161-165.

Grelen, H.E. 1962. Succession on cleared sandhills in northwest Florida. Amer. Midl. Nat. 67:36-44.

Greulach, V.A. and J.E. Adams. 1962. Plants, An Introduction to Modern Botany. John Wiley and Sons, Inc., N.Y. 557 pp.

Hair, D. and A.H. Ulrich. 1969. The demand and price situation for forest products 1968-69. Misc. Publ. No. 1086 U.S.D.A. For. Ser., Washington, D.C.

Hairston, N.G., G.E. Smith and L.B. Slobodkin. 1960. Community structure, population control, and competition. Amer. Nat. 94:421-425.

Hamilton, W.J.,Jr. 1943a. The Mammals of Eastern United States. Comstock Publishing Co., Ithaca, N.Y. 432 pp.

1943b. Caterpillars as food of the gray squirrel. J. of Mammalogy. 24:104.

Hanson, H.C. and E.D. Churchill. 1961. The Plant Community. Reinhold Publishing Corp., N.Y. 218 pp.

Harlow, R.F. 1959. An evaluation of white-tailed deer habitat in Florida. Florida Game and Fresh Water Fish Commission. Tech. Bull. No. 5.

Harper, R.M. 1902. Taxodium distichum and related species, with notes on some geological factors influencing their distribution. Bull. Tor. Bot. Club 29:383-399.

Hatchell, G.E. 1964. Small mammal species and populations in the loblolly-short leaf pine forest type of Louisiana. U.S. Forest Service Research Paper SO-10. Southern Forest Exp. Sta., New Orleans, La.

Hazen, W.E. 1964. Readings in Population and Community Ecology. W.B. Saunders Co., Phillidelphi

Heald, E.J. 1970. The production of organic detritus in south Florida estuary. Ph.D. Diss., University of Miami, Miami. 110 pp.

Heck, N.H. 1947. Earthquake history of the United States. U.S. Coast and Geodetic Survey. Serial No. 609. 83 pp.

Henderson, L.J. 1913. The Fitness of the Environment. Beacon Press, Boston. 317 pp.

Heubeck, E.K. 1967. A survey of the parasites of the cattle egret (Bibulcus Ibis). M.S. Thesis, University of Florida, Gainesville. 41 pp.

Heyward, F. 1939a. The relation of fire to stand composition of longleaf pine forests. Ecol. 20:287-304.

1939b. Some mosture relationships of soils from burned and unburned longleaf pine forests. Soil Sci. 47:313-327.

Hilmon, J.B. 1969. Autecology of saw palmetto (Serenoa repens [Bartr.] Small). Ph.D. Diss., Duke University, Durham, N.C. 190 pp.

Holm, L.G., L.W. Weldon, and R.D. Blackburn. 1969. Aquatic weeds. Sci. 166:699-709.

Hough, W.A. 1968. Fuel consumption and fire behavior of hazard reduction burns. Forest Service Research Paper SE-36. Southeast Exp. Sta. USDA.

Howell, A.H. 1932. Florida Bird Life. Coward-McCann, Inc., N.Y.

Hutchinson, G.E. 1959. Homage to Santa Rosalia or why are there so many kinds of animals? Amer. Nat. 93:145-159.

1965. The Ecological Theatre and the Evolutionary Play. Yale University Press, New Haven. 152 pp.

Jennings, W.L. 1958. The ecological distribution of bats in Florida. Ph.D. Diss., University of Florida, Gainesville.

Johnson, C.H. 1967. Important medicinal plants of Florida. Florida Dept. of Agr., Tallahassee. 51 pp.

Jorgensen, C.G. and C.A. Newport (eds.) 1969. Douglas fir supply study. Alternative programs for increasing timber supplies from National Forest Lands. Regions five and six. Pacific Northwest Forest and Range Exp. Sta., Forest Service, USDA. 53 pp.

Kahl, M.P. 1964. Food ecology of the wood stork (Mycteria americana) in Florida. Ecol. Monogr. 34:97-117.

Kormondy, E.J. 1965. Readings in Ecology. Prentice Hall, Englewood Cliffs, N.J. 219 pp.

1969. Concepts of Ecology. Prentice Hall, Englewood Cliffs, N.J. 209 pp.

Kramer, P.J., W.S. Riley, and T.T. Bannister. 1952. Gas exchange of cypress knees. Ecol. 33(1):117-121.

Krochmal, A., R.S. Walters, and R.M. Doughty. 1969. A guide to medicinal plants of Appalachia. U.S.D.A. Forest Research Papser NE-138. Northeastern Forest Exp. Sta., Upper Darby, Pa. 291 pp.

Kurtz, H. 1942. Florida dune and scrub vegetation and geology. Fla. Geol. Survey Bull. 23. 154 pp.

Kurtz, H. and D. Demaree. 1934. Cypress buttresses and knees in relation to water and air. Ecol. 34:36-41.

Kurtz, H., R.K. Godfrey, and K.E. Wagner. 1962. Trees of Northern Florida. University of Florida Press, Gainesville. 311 pp.

Laessle, A.M. 1939. A study of the food habits of quail in peninsular Florida. M.S. Thesis, University of Florida, Gainesville. 52 pp.

1942. The plant communities of the Welaka area. Univ. of Florida Biol. Sci. Ser. 4:1-143.

1958. The origin and successional relationship of sandhill vegetation and sand pine scrub. Ecol. Monog. 28:361-387.

1965. Spacing and decomposition in natural stands of sand pine. Ecol. 46:65-72.

1968. Relationship of sand pine scrub to former shore lines. Fla. Acad. of Science. 30:269-286.

Laessle, A.M. and C.D. Monk. 1961. Some live oak forests of northeastern Florida. Quart. J. Fla. Acad. of Science. 24(1):39-55.

LaMonte, F. 1958. North American Game Fishes. Doubleday and Co.,Inc., Garden City, N.Y. 206 pp.

Layne, J.N. 1970. Terrestrial wildlife of the Oklawaha regional ecosystem. pp. 35-42. In: Environmental impact of the Cross Florida Barge Canal with special emphasis on the Oklawaha regional ecosystem. Florida Defenders of the Environment, Gainesville.

Lemon, E. 1963. Energy and water balance of plant communities. Chapt. 5. In: L.T. Evans (ed.) Environmental Control of Plant Growth. Academic Press, N.Y. 449 pp.

Likens, G.F., F.H. Bormann, N.M. Johnson, D.W. Fisher, and R.S. Pierce. 1970. Effects of forest cutting and herbicide treatment on nutrient budgets in the Hubbard Brook watershed-ecosystem. Ecol. Monogr. 40:23-47.

Lindeman, R.L. 1942. The trophic-dynamic aspect of ecology. Ecol. 23: 399-418.

Lotka, A.J. 1956. Elements of Mathematical Biology Dover Publ., N.Y. 465 pp.

Loveless, C.M. 1959. The everglades deer herd life history and management. Florida Game and Fresh Water Fish Commission. Tech. Bull. No. 6.

Lugo, A.E. 1969. Water, carbon and energy budgets for a granite outcrop system. Ph.D. Diss., University of North Carolina, Chapel Hill.

1970a. Ecosystems and man. Fla. Nat. July, pp. 89-92.

1970b. Ecological role of fertilizers in relation to forest productivity and dollar subsidy by man. pp. 21-33. In: Proceedings of Florida Section Society of American Foresters, Gainesville, Fla.

Lugo, A.E. and S.C. Snedaker (eds.) 1971. Readings on Ecological Systems: Their Function and Relation to Man. M.S.S. Publ. Co., N.Y. 330 pp.

Lugo, A.E., S.C. Snedaker, S. Bayley, and H.T. Odum. 1971. Models for planning and research for the South Florida Environmental Study. Final Report submitted to the National Park Service, August, 1971. 123 pp.

Lugo, A.E., S.C. Snedaker and J. F. Gamble. 1972. Models of matter flow in a southern mixed hardwood forest in Florida: Preliminary results. Third National Symposium on Radioecology, May 10-12, 1971. Oak Ridge, Tenn. (in press)

MacNeil, F.S. 1949. Pleistocene shore lines in Florida and Georgia. U.S. Geol. Surv. Prof. Paper 221-F. pp. 95-107.

Margalef, R. 1963. On certain unifying principles in ecology. Amer. Nat. 47:357-374.

1968. Perspectives in Ecological Theory. University of Chicago Press. 109 pp.

Martin, R.A. 1966. Eternal Spring. Great Outdoors Publishing Co., St. Petersburg, Fla. 264 pp.

McArthur, R.H. 1965. Patterns of species diversity. Biol. Rev. 40:510-533.

McArthur, R.H. and J.H. Connell. 1966. The Biology of Populations. John Wiley & Sons,N.Y.200p.

McCurrach, J.C. 1960. Palms of the World. Harper and Brothers, N.Y. 290 pp.

McLane, W.M. 1955. The fishes of the St. John's River system. Ph.D. Diss., University of Florida, Gainesville. 361 pp.

Meyer, B.S., D.B. Anderson, and R.H. Bohning. 1960. Introduction to Plant Physiology. D. Van Nostrand Co., Inc., N.Y. 541 pp.

Michael, V.C. 1951. Quail preference for seed of farm crops. M.S. Thesis, University of Florida, Gainesville. 41 pp.

Miller, J.E. 1970. Nesting sites selected by bobwhite quail in south Florida flatwoods. M.S. Thesis, University of Florida, Gainesville.

Monk, C.D. 1960. A preliminary study on the relationships between the vegetation of a mesic hammock and a sand hill community. Quart. J. Fla. Acad. Sci. 23:1-12.

1965. Southern mixed hardwood forests of north central Florida. Ecol. Monogr. 35:335-354.

1966. An ecological study of hardwood swamps in north central Florida. Ecol. 47: 649-654.

1966. An ecological significance of evergreeness. Ecol. 47:504-505.

1967. Tree species diversity in the eastern decidious forests with particular reference to north central Florida. Amer. Nat. 101:173-187.

1968. Successional environmental relationships of the forest vegetation of north-central Florida. Amer. Midl. Nat. 79:441-457.

Monk, C.D. and T.W. Brown. 1965. Ecological considerations of cypress heads in north central Florida. Amer. Midl. Nat. 74(1):126-140.

Monk, C.D. and J.T. McGinnis. 1966. Tree species diversity in six forest types in north central Florida. J. Ecol. 54:341-344.

Mulvania, M. 1931. Ecological survey of a Florida scrub. Ecol. 12(3):528-540.

National Academy of Sciences. 1969. Eutrophication: Causes, Consequences, Correctives. Washington, D.C. 661 pp.

Newman, C. and E. Griffin. 1950. Deer and turkey habitats and populations of Florida. Florida Game and Fresh Water Fish Commission. Tech. Bull. No. 1.

Odum, E.P. 1962. Relationship between structure and function in the ecosystem. Jap. J. Ecol. 12:108-118.

1963. Ecology. Holt, Rinehart and Winston, N.Y. 152 pp.

1968. Energy flow in ecosystems: A historical review. Amer. Zool. 8:11-18.

1971. Fundamentals of Ecology. W.B. Saunders Co., Philadelphia. 574 pp.

Odum, H.T. 1956. Efficiencies, size of organisms and community structure. Ecol. 37:592-597.

1960. Ecological potential and analogue circuits for the ecosystem. Amer. Scient. March pp. 1-8.

1962. Ecological tools and their use - man and the ecosystem. pp. 57-75. In: Proceedings of the Lockwood Conf. on the Suburban Forest and Ecology. P.E. Waggoner and D.D. Ovington (eds.) Conn. Agr. Exp. Sta. Bull. 652.

1963. Limits of remote ecosystems containing man. Amer. Biol. Tea. 25:429-443.

1967a. Energetics of the world food production. Chapter 3. In: The World Food Problem. Report to the President's Science Advisory Committee. Vol. e, The White House.

1967b. Work circuits and systems stress. pp. 81-138. In: Symposium in primary productivity and mineral cycling in natural ecosystems. Univ. of Main Press.

1971. Environment, Power and Society. John Wiley Interscience, N.Y. 331 pp.

dum, H.T., J.E. Cantlon, and L.S. Kornicker. 1960. An organizational hierarchy postulate for the interpretation of species individual distributions, species entropy, ecosystem evolution, and the meaning of a species variety index. Ecol. 41:395-399.

dum, H.T., W. McConnell, and W. Abbott. 1959. The chlorophyll A of communities. Publ. Inst. Mar. Sci. Univ. Tex. 5:65-96.

dum, H.T., A.M. Moore, and L.A. Burns. 1970. Hydrogen budgets and compartments in the rain forest. Chapter H-6. In: A tropical rain forest, H.T. Odum and R.F. Pigeon (eds.). Atomic Energy Commission, Division Technical Information, Washington, D.C.

dum, H.T. and R.C. Pinkerton. 1955. Times speed regulator, the optimum efficiency for maximum output in physical and biological systems. Amer. Scient. 43:331-343.

lson, J. 1963. Energy storage and the balance of producers and decomposers in ecological systems. Ecol. 44:322-331.

osting, H.G. 1956. The Study of Plant Communities. W.H. Freeman and Co., San Francisco.440pp.

tt, E.R. and L.H. Chazel. 1966. Ocali Country, Kingdom of the Sun. Marion Publ.

vington, J.D. 1962. Quantitative ecology and the woodland ecosystem concept. pp. 103-192. In: Advances in Ecological Research, No. 1. Academic Press, N.Y.

1968. Some factors affecting nutrient distribution within ecosystems. pp. 95-105. In: The function of the ecosystem at the primary productivity level. UNESCO.

ark, O. 1945. Observations concerning the future of ecology. Ecol. 26:1-9.

arrott, R.T. 1967. A study of wiregrass (Aristida stricta Michx.) with particular reference to fire. M.S. Thesis, Duke University, Durham, N.C.

atten, B. 1959. An introduction to the cybernetics of the ecosystem: the trophic dynamic aspect. Ecol. 40:221-231.

atten, B.C. and W. Witkamp. 1967. Systems analysis of ^{134}cesium kinetics in terrestrial microcosms. Ecol. 48:813-824.

earson, P.G. 1954. Mammals of Gulf Hammock, Levy County, Florida. Amer. Midl. Nat. 51(2): 468-480.

enfound, W.T. 1952. Southern swamps and marshes. Bot. Rev. 18:413-446.

enfound, W.T. and T.T. Earle. 1948. The biology of water hyacinth. Ecol. Monogr. 18:447-472.

enfound, W.T. andA.G. Watkins. 1937. Phytosociological studies in the pinelands of southeastern Louisiana. Amer. Midl. Nat. 18:661-682.

essin, L.J. 1934. Annual ring formation in Pinus palustris seedlings. Amer. J. Bot.pp.599-603.

1938. The effect of vegetation on the growth of long-leaf pine seedlings. Ecol. Monogr. 8:115-149.

eterson, R.T. 1947. A Field Guide to the Birds. Houghton Mifflin Co., Boston,Mass. 290 pp.

hillipson, J. 1966. Ecological Energetics. St. Martins Press, N.Y. 57 pp.

irkle, E.C. and H.K. Brooks. 1959. Origin and hydrology of Orange Lake, Santa Fe Lake, and Levy Prairie Lakes of north-central peninsular Florida. Journ. Geol. 67:302-317.

irkle, E.C., W.H. Yoho and A.T. Allen. 1964. Origin of the silica sand deposits of the Lake Wales Ridge area of Florida. Economic Geol. 59:1107-1139.

irkle, W.A. 1971. The offset course of the St. Johns River, Florida. Southeastern Geology. 13:39-59.

ope, C.H. 1939. Turtles of the United States and Canada. Alfred A. Knopf, N.Y. 343 pp.

ournelle, G.H. 1947. Mammals of a swamp region near Gainesville, Fla. M.S. Thesis, University of Florida, Gainesville.

1950. Mammals of a north Florida swamp. J. of Mammalogy. 3(3):310-319.

Puri, H.S., and R.O. Vernon. 1964. Summary of the geology of Florida and a guidebook to the classic exposures. Florida Geol. Surv. Spec. Pub. 5, revised, 312 pp.

Quarterman, E. and C. Keever. 1962. Southern mixed hardwood forest: climax in the southeastern coastal plain, U.S.A. Ecol. Monogr. 32:167-185.

Quasler, A. 1965. General principles of systems analysis. pp. 313-33. In: T.H. Waterman and H.J. Morowitz (eds.) Theoretical and Mathematical Biology. Blaisdell, N.Y.

Redfield, A.C. 1958. The biological control of chemical factors in the environment. Amer. Scient. 46:205-222.

Reichle, D.E. (ed.) 1970. Analysis of Temperate Forest Ecosystems. Springer-Verlag, N.Y. 304 pp.

Reid, G.K. 1961. Ecology of Inland Waters and Estuaries. Reinhold Publ. Co.,N.Y. 375 pp.

Reifsnyder, W.E. and H.W. Lull. 1965. Radiant energy in relation to forests. Tech. Bull. No. 13444, U.S.D.A. For. Ser. 111 pp.

Revelle, R. 1963. Water. Sci. American, September.

Ripley, T.H., L.P. Wilhite, R.L. Downing, and R.F. Harlow. 1962. Game food plants in slash-longleaf flatwoods. Proc. 16th Annu. Conf. Southeastern Assoc. of Game & Fish Commissioners. 10 pp.

Robbins, C.S., B. Brunn, and H.S. Zim. 1966. A Guide to Field Identification: Birds of Nort America. Western Publishing Co., Inc., N.Y. 340 pp.

Rodin, L.E. and N.I. Bazilevich. 1967. Production and Mineral Cycling in Terrestrial Vegetation. Trans. by Scripta Technica Ltd. Edinburgh, Oliver and Boyd. 288 pp.

Romans, B. 1775. A Concise Natural History of East and West Florida. New York.

Sculthorpe, C.D. 1967. The Biology of Aquatic Vascular Plants. Edward Arnold, Ltd.London. 6

Sears, P.B. 1964. Ecology-A subversive subject. BioScience. July 11-13.

1967. Beyond the forest. Amer. Scient. 55:338-346.

Shelford, V.E. 1963. The Ecology of North America. University of Illinois Press, Urbana. 61

Slobodkin, L.B. 1962. Energy in animal ecology. Adv. Ecol. Res. 1:69-101.

1968. Aspects of the future of ecology. BioScience. 18:16-23.

Snedaker, S.C. 1963. Some aspects of the ecology of the Florida sandhills. M.S. Thesis, University of Florida, Gainesville. 54 pp.

Sopper, W.E. and H.W. Lull (eds.) 1967. Forest Hydrology. Pergamon Press, N.Y. 813 pp.

Sorokin, J.I. 1965. On the trophic role of chemosynthesis and bacterial biosynthesis in wate bodies. pp. 189-205. In: C.R. Goldman (ed.) Primary productivity in aquatic environments. Mem. Ist. Ital. Idrobiol., 18 Suppl. Univeristy of California Press, Berkeley.

Spurr, S.H. 1964. Forest Ecology. The Ronald Press, N.Y. 352 pp.

Stoddard, H.L. 1926. Report on cooperative quail investigation: 1925-1926 with preliminary recommendations for the development of quail perserves. Quail Study Fund for Southern Georgia and Northern Florida. 62 pp.

1932. The Bobwhite Quail, Its Habits, Preservation, and Increase. Charles Scribner's Sons, N.Y.

Strode, D.D. 1954. The Ocala deer herd. Florida Game and Fresh Water Fish Commission. Publ. No. 1. Pittman-Robertson Projects.

Talmage, R.V. and G.D. Buchanan. 1954. The armadillo: A Review of its natural history, ecology, anatomy, and reproductive physiology. The Rice Institute Pamphlet 41(2):1-135.

Telford, S.R. 1965. Some biogeographical aspects of the Floridian herpetofauna. Acta Herpetologica Japonica, 2:16-21.

Thomas, W.A. 1969. Accumulation and cycling of calcium by dogwood trees. Ecol. Monogr. 39:101-120.

Todd, D.K. (ed.) 1970. The Water Encyclopedia. Water Information Center, Port Washington, N.Y. 551 pp.

Tucker, J.A. 1968. Florida Birds. Lewis S. Maxwell, Publ., Tampa, Fla. 120 pp.

Van Beneden, J.P. 1876. Animal parasites and messmates. In: Allee, W.C., A.E. Emerson, O. Park, T. Park and K. P. Schmidt. 1949. Principles of Animal Ecology. W.B. Saunders Co., Philadelphia. 837 pp.

Van Doren, M. (ed.) 1928. Travels of William Bartram. Dover Publications,N.Y. 414 pp.

Van Dyne, G.M. (ed.) 1969. The Ecosystem Concept in Natural Resource Management. Academic Press, N.Y. 383 pp.

Vernon, R.O. 1947. Cypress domes. Sci. 105:97-99.

1951. Geology of Citrus and Levy Counties, Florida. Fla. Geol. Survey Bull. 33, 256 pp.

Watt, K.E.F. 1966. Systems Analysis in Ecology. Academic Press, N.Y. 216 pp.

1968. Ecology and Resource Management. McGraw-Hill Book Co., N.Y. 450 pp.

Watts, W.A. 1969. A pollen diagram from Mud Lake, Marion County, north-central Florida. Geol. Soc. Am., 80:631-642.

Walter, H. and H. Lieth. 1960. Klimadiagram weltatlos. G. Fischer, jence.

Ward, D.B. 1968. Checklist of the vascular flora of Florida, Part I. Florida Agr. Exp. Sta. Tech. Bull. 726. 72 pp.

Went, F.W. and N. Stark. 1968. Mycorrhiza. BioScience. 18:1035-1039.

West, E. and L.E. Arnold. 1956. The Native Trees of Florida. Univeristy of Florida Press, Gainesville. 218 pp.

Wharton, C.H. 1958. The ecology of the cottonmouths, Agkistrodon piscivorous (Lacepede) of Sea Horse Key, Florida. Ph.D. Diss., University of Florida, Gainesville. 217 pp.

White, W.A. 1958. Some geomorphic features at central peninsular Florida. Fla. Geol. Survey Bull. 41. 92 pp.

1970. The geomorphology of the Florida peninsula. Fla. Geol. Survey Bull. 41,92pp.

Whitford, L.A. 1956. A theory on the formation of cypress knees. J. Elisha Mitchell Scient. Soc. 72(1):80-83.

Whitel, L. 1967. The historical roots of our ecological crisis. Sci. 155:1203-1207.

Whittaker, R.H. 1970. Communities and Ecosystems, The McMillan Co., Toronto. 162 pp.

Woodwell, G.M. 1967. Toxic substances and ecological cycles. Scientific Amer. 216:24-31.

Woodwell, G.M., C.F. Wurster and P.S. Isaacson. 1967. DDT residues in an east coast estuary: A Case of biological concentration of a persistent insecticide. Sci. 156:821-824.

Woodwell, G.M. and M.H. Smith (eds.) 1969. Diversity and stability in ecological systems. Brookhaven symposia in biology No. 22. BNL 50175 (C-56).

Yarlett, L.L. 1965. Important native grasses for range conservation in Florida. U.S.D.A. Soil Conservation Service.

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